american journal of agricultural economics

Vol. 50 No. 1 February 1968

ARTICLES

COMMUNICATIONS

REVIEWS

ANNOUNCEMENTS

P, 6 6 3 4

NEWS NOTES

Congressional Bargaining in Agriculture: Cotton

Barry C. Field

Bargaining among sectional cotton interests in Congress was particularly intense in 1953-54, when a substantial reduction had to be made in the national allotment and then allocated to the various cotton-producing states. Due largely to congressional constraints on committees to achieve some mutually satisfactory aggregation of preferences, this event can be treated as a two-person, mixed-motive bargaining game between eastern and western cotton interests. Through a series of offers and counteroffers, a final solution was reached such that each 1-percent acreage reduction in the east was accompanied by a 2-percent reduction in the west. Furthermore, these final "terms of trade" are the same as were reached in a similar instance of bargaining among cotton interests in 1949, implying some stability in the congressional bargaining process through the course of time.

THE extent to which legislative processes are characterized by vigorous and protracted bargaining among groups of legislators has been noted by numerous investigators [4, pp. 333–343; 19, p. 368; 27, p. 131]. This phenomenon has been one of the distinguishing features of the process leading to enactment of farm legislation in the U.S. Congress. The abundance of potential cleavages on commodity and geographic lines [10], the relatively high constituency orientation of farm-state legislators [11], and the overall strategic need of a relatively high degree of cohesion within the agricultural ranks [1, pp. 111–120; 9, pp. 233–236] have all contributed to this result.

One of the more conspicuous instances of intra-commodity bargaining in the post-World War II period was among cotton interests in the early 1950's. The task of utilizing a "protectionist" economic policy, at the same time adapting it to changes in the structure of the protected industry, engendered severe controversy among sectional cotton groups, thereby necessitating explicit bargaining action to construct mutually preferred programs. Furthermore, the public record contains sufficient information for a complete depiction of this phenomenon, including the offers, counteroffers, and final "terms of trade" among the participating groups of legislators. It also allows a comparison of the outcome achieved through bargaining with the regional distribution of power implied solely by the geographical distribution of legislators' constituencies.

Market conditions for U.S. cotton producers were favorable for several years following World War II; both domestic and international demand for raw cotton were strong, and prices reached relatively high levels during the period. Producers responded by expanding acreage markedly, an expansion which continued until 1953, with the exception of 1950. In ac-

Barry C. Field *is assistant professor of economics at The Center for Natural Resources Policy Studies, The George Washington University.*

cordance with provisions of the Agricultural Act of 1938, as amended, acreage allotments and marketing quotas were put into effect in 1950, and again from 1954 to the present. This postwar expansion of cotton acreage did not take place at the same rate in all parts of the cotton belt. The increase was much more rapid in irrigated and highly mechanized areas of the western states—in California, Arizona, New Mexico, and western Texas—than in the "historic" cotton areas stretching from eastern Texas to the Atlantic coast. This increased the economic heterogeneity of the cotton belt, which in turn made more heterogeneous the policy preferences on cotton programs and increased the intensity of western preferences with respect to securing "equitable" treatment vis-à-vis the other cotton states.[1] The interregional bargaining over cotton acreage that took place in Congress in 1953-54 is the main topic of this paper.

Harvested acreage in 1953 was 24.3 million acres. Under the existing statutory formula, the Secretary of Agriculture was required to announce a national allotment for 1954 of about 17 million acres, a reduction of almost 40 percent from the previous year. This was felt to be excessive by all parties concerned. In effect, the policy status quo, since it involved the application of historic formulas to substantially changed economic conditions, implied drastic changes in the economic status quo, and action was initiated to reduce the amount of adjustment required of cotton producers. Furthermore, the cutback implied by the existing law would have been relatively greater in the West than in the East because of the former's more recent production history. Hence, the legislative problems were (1) to establish a minimum national allotment somewhat greater than the prospective 17 million acres but less than the planted acreage of 1953, and (2) to allocate the resulting acreage reduction to the states comprising the cotton belt.

After prolonged bargaining in the House, a bill was passed establishing a minimum national allotment of 22.5 million acres and a complicated allocation formula, one part of which involved maximum individual state cutbacks of 29½ percent of the 1952 planted acreage. The Senate, however, did not take up the matter until early 1954. By this time, the Secretary had announced a 1954 allotment of 17 million acres, allocated in accordance with the old law. Therefore, the policy imperative in the Senate was to add back enough acreage to reach the desired level as well as to devise some acceptable allocation formula. The final Senate bill called for additional acreage sufficient to give a national allotment of 21 million acres, to be distributed according to the old formula, plus 315,000 of "hardship" acreage, of which half was to be shared by the states of California, Ari-

[1] The postwar changes in economic structure throughout the cotton belt are described in detail in my Ph.D. thesis [7, pp. 10–94]. On the notion of preference intensity, see Coleman [3].

zona, and New Mexico, and half by all of the remaining states; in addition, no state was to be cut more than 33 percent of its 1952 planted cotton acreage. In conference, the Senate bill prevailed, and the law was finally approved just before planting time.[2]

It is essentially correct, though of course somewhat simplified, to treat this set of events as a two-person, mixed-motive bargaining situation, with the "West," comprised of California, New Mexico, Arizona, and western Texas, against the "East," containing all of the other cotton-producing states.[3] The relevant preferences of the two parties were two-dimensional, including the total size and the distributive shares of the national acreage allotment. For a given national acreage allotment in terms of total acres, the preferences of the East and West were strictly opposed, with each preferring larger to smaller shares of the total. The one obvious limit to this monotonicity was that of the western interests, who presumably were indifferent among all shares that would have used more than the supply of readily available land in the region. The two sides also differed with respect to total size of the national allotment.

One of the basic competitive motives of the eastern cotton interests was to control the expansion of cotton production in the West. Given the general congressional power structure, an acreage allotment program was well designed to effectuate this, provided that it was not allowed to lapse in the future. The preferences of the eastern group would therefore drop off rapidly at two points: at the upper end, the point would be a national allotment large enough to lead to buildup in the Commodity Credit Corporation inventories sufficient to discredit the whole program; at the lower end, the point would be an allotment sufficiently small to control production so effectively that in future years acreage controls could be abandoned. That is, the eastern interests desired an allotment size that would control production to some extent but would not be successful in the sense of leading eventually to "free" planting.[4] The preferences of the West regarding size of the national allotment were somewhat different. Its most preferred alternative was less than that of the East, since this would

[2] PL 83-290, approved January 30, 1954. This measure also contained many detailed provisions dealing with allocation of acreage within states and countries, on which some compromise was achieved in conference.

[3] States in the eastern group include Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia, Arkansas, Illinois, Louisiana, Kentucky, Mississippi, Missouri, Tennessee, Oklahoma, and eastern Texas.

[4] The eastern group had been making efforts to use the acreage allotment program toward this end for a number of years prior to 1953. One of the attempts was to redefine the notion of "surplus" so as to make it easier to impose acreage restrictions; indeed, the lapse in acreage restrictions from 1951 to 1953 would not have occurred had the eastern group had its way, for this allowed the West to make further competitive inroads which then had to be taken into account in the bargaining of 1953-54. The conflict over redefinition of "surplus" can be reconstructed from congressional records [20; 22, pp. 1139-99; 23, pp. 2400, 3520, 3934–58, 4029].

have increased the probability of suspending allotments in future years.[5] Looked at in straightforward marginal terms, the preferences of the West would have increased monotonically with smaller national allotments to the point where the cost in present acreage exceeded the return in terms of the probability of increased future plantings, should the surplus be reduced enough to permit abandoning controls in the future. On the other hand, the point at which there was a marked fall-off in preference as allotments increased in size probably would not have been substantially different between East and West; if the allotment program was discredited, which it might have been had the "surplus" become too visible, the likelihood of getting basic and mutually disadvantageous changes in the whole program, say outright control of output rather than simply acreage, would have been heightened considerably.

Both the East and the West thus preferred some action to reduce the amount by which acreage would be cut back. However, although they cooperated to achieve this result, direct conflict occurred on the exact amount of the reduction and its regional distribution; hence, the mixed-motive nature of the bargaining [8, 18, 26]. Although there were no record votes taken on this issue, available evidence suggests strongly that both eastern and western cotton interests favored the resulting allotment formula over the one that would have resulted had there been no legislative action [24, p. 10069; 25, p. 168]. A sufficient condition such that "Pareto-optimality" among cotton-belt interests resulted from a true bargaining process is that each side possessed a veto power over possible formulas, since this would have ensured at least the status quo for both sides [2, p. 94; 17, p. 107]. While mutual veto power is not a necessary condition for this result, the other sufficient conditions seem implausible enough in the present case that they need not be seriously entertained.[6]

Were one to have predicted the outcome of the policy process solely on the basis of the geographical distribution of committee membership, one would have concluded that, owing to the dominant position of the eastern cotton interests on the agricultural committees, substantially all of the reduction in national acreage would have been placed on producers in the western region. In the 81st through the 84th Congresses, or from 1949 to 1956, legislators from the eastern cotton states accounted for over 40 percent of the total membership of the House Committee on Agriculture

[5] Along with the future relaxation of acreage restrictions, the western group of course wanted a lowering of price supports, since this would serve to discourage production in the East and allow acreage to shift westward. They therefore supported the Farm Bureau position on cotton [24, p. 10666].

[6] In the absence of a veto power by one side, programs would be preferred by that side to the status quo only if (1) the programs chosen by the strong side, and optimal from its own standpoint, also happened to be preferred by the weak side, or (2) the strong side adopted an altruistic position and voluntarily limited itself to policy alternatives preferred also by the weak side.

(Table 1). In the 83rd Congress (1953–54) this figure was actually over 50 percent. Membership on the Senate Committee on Agriculture and Forestry was substantially the same, with the exception of the 83rd Congress, during which the proportion of members having constituencies in the eastern cotton states dropped to 33 percent. There is, of course, a coincidental cleavage of committee memberships along party lines, with the bulk of the cotton-state legislators being Democrats. These cleavages held also for the Subcommittee on Cotton of the House Committee on Agriculture. Among legislators from cotton states only, it is clear that the western interests could have been consistently and overwhelmingly outvoted, so that one of their tactics might have been to form coalitions with legislators from noncotton regions against the eastern cotton group. In the bargaining of 1953–54, however, this opportunity was not readily available, since the bill establishing the national cotton allotment and its allocation was confined to this one commodity.[7]

Table 1. Regional distribution of House and Senate agricultural committees, 1949–1956[a]

Congress	Total membership		Cotton states					Other states	
			East[b]			West[c]			
	D	R	D	R	Percent	D	R	D	R
House Commitee on Agriculture									
81st (1949-50)	17	10	11	0	(40.7)[d]	1	1	5	9
82nd (1951-52)	17	13	13	1	(46.7)	1	1	3	11
83rd (1953-54)	14	16	13	3	(53.3)	0	1	1	12
84th (1955-56)	19	15	14	1	(44.1)	1	0	4	14
Senate Committee on Agriculture and Forestry									
81st (1949-50)	8	5	5	1	(46.2)	1	0	2	4
82nd (1951-52)	7	6	5	1	(46.2)	1	0	1	5
83rd (1953-54)	7	8	5	0	(33.3)	1	0	1	8
84th (1955-56)	8	7	7	0	(46.7)	0	0	1	7

[a] Includes members announced at beginning of each Congress.
[b] Includes Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia, Arkansas, Louisiana, Kentucky, Mississippi, Missouri, Tennessee, Texas, and Oklahoma.
[c] Includes California, Arizona, and New Mexico.
[d] Figures in parentheses are percentages of total membership represented by members from eastern cotton states, disregarding party affiliation.
Source: Committee calendars.

Though a direct voting veto was not available, a veto might have been operative through another process, and indeed it is only this phenomenon that could plausibly explain the extensive bargaining that in fact took place between East and West. This is the constraint put on committee

[7] The strategic possibilities open to western interests are examined more fully in my Ph.D. thesis [7, pp. 153–162].

work by the full chambers to the effect that any bills reported must represent preference aggregations which are preferred to the status quo by all interested parties, though they may be only marginally preferred by one group whereas for others they represent substantial improvements on the existing situation. Available studies suggest the existence of this kind of constraint, though its actual power is still in some doubt.

An implicit pressure on committees to achieve some mutually satisfactory agreement among groups before reporting bills was found by Matthews in his study of the Senate. Furthermore, he presents data to show that agreement among committee members is associated with passage of bills on the floor; the inference one draws is that an increasing rate of agreement among committee members is associated with increasing probability that the measure will be passed on the floor [14, pp. 168–171]. In his studies of the appropriations process, Fenno discusses the significance of committee unity in reporting bills for enactment, with the committee's prestige and power depending on the extent to which they were able to reach agreement among themselves in committee deliberations [5, p. 323]. Although Fenno's conclusions are tentative, they at least suggest the phenomenon in question.[8] The extent to which unresolved conflict in committee leads to power struggles on the floor has been noted in a study of the House Committee on Education and Labor [15, pp. 137–169]. The pressures on the House Committee on Ways and Means to achieve a satisfactory adjustment of conflicting demands before reporting bills is another instance of this [13, pp. 930–931].

These studies seem to point to the conclusion that both the House and the Senate expect a level of intra-committee agreement sufficiently high to hold up on the floor.[9] For the question at issue here, this expectation would mean that even though representatives of the eastern section of the cotton belt were able, by virtue of their superior numbers, to determine the essential character of the cotton allotment program, there was pressure on them to write the bill in such a way that it would also be preferred by the western interests. For the West, this pressure changed the situation from one of decisive underrepresentation on the committees to one in which some bargaining could take place. It is probably correct to think of this kind of constraint on committee action as operative in general and in the long run. In any single instance of policy bargaining, the

[8] In his recent work Fenno explores this relationship at some length [6].

[9] A corollary to this is that one expects to find higher rates of cohesion, on roll-call votes in the full chambers, among members of the reporting committees than among all members. This holds true for postwar agricultural legislation. Using Rice's index of cohesion [16], the cohesion among Democratic members of the House Committee on Agriculture, on 116 roll-call votes between 1947 and 1965 dealing with agricultural issues, was calculated to be 76.4, compared to 61.7 for all Democrats. For Republicans, cohesion was 65.8 for committee members and 51.9 for the full party [7, pp. 256–276].

outcome would depend both on the content of the bill—say whether it was a temporary measure or one that promised to set the general tone of cotton programs for the future—and on the strategic possibilities at the time—for example, whether or not it was part of a general agricultural coalition on an omnibus bill.[10] With the data available for the 1953-54 allotment bill it is possible to show clearly that the East was in fact drawn into a bargaining relationship with the West. Furthermore, with the help of several assumptions we can measure the amount by which the eastern group was required to retreat from its most preferred policy alternative to secure the cooperation of the West.

The proposals and counterproposals in the bargaining were in the form of formulas, each of which established both a total national allotment and a distribution to the states. For each cotton-producing state, then, as well as for the nation, the formulas implied some percentage reduction from previous plantings (Table 2). By aggregating the state figures into "East" and "West," we can depict the essential characteristics of the bargaining process diagrammatically. In 1952 the three states of California, Arizona, and New Mexico accounted for approximately 10 percent of the national planted acreage. If X is used to designate the national planted acreage in 1952, X_e and X_w the acreage in the East

Table 2. Comparison of proportionate reductions in state cotton allotments implied by alternatively proposed allocation formulas, 83rd Congress (1953-54)

State	No change	First western preference	Second western preference	First eastern preference	Third western preference	Second eastern preference	Bill enacted in House	Bill finally approved
	...... *prospective 1954 allotment as percentage of 1952 planted acreage*							
Alabama	72	75	81	92	88	92	92	87
Georgia	69	75	82	89	84	89	89	83
N. Carolina	69	75	81	88	85	88	88	83
S. Carolina	70	75	84	90	86	90	90	84
Arkansas	79	75	87	102	97	102	102	97
Louisiana	71	75	84	91	86	91	91	83
Mississippi	73	75	83	94	89	94	94	87
Missouri	76	75	88	98	95	88	98	94
Tennessee	67	75	81	87	83	87	87	81
Texas	61	75	84	78	77	78	78	74
Oklahoma	71	75	89	91	87	91	91	86
"East"	67	75	84	86	83	85	86	81
Arizona	46	75	78	60	73	65	70	67
California	49	75	81	64	72	68	70	67
New Mexico	58	75	85	75	77	78	75	76
"West"	49	75	81	64	73	68	71	68
U.S.	65	75	84	84	82	84	85	80

Source: *Congressional Record*. Vol. 100 [25, p. 169] for bill as finally approved; Vol. 99 [24, pp. 10663–65] for all other information.

[10] Some of these strategic possibilities, discussed in connection with passage of the Agricultural Act of 1958, are covered by Jones [12].

and West, respectively, and x, x_e and x_w the percentage reductions in these acreages from 1952 to 1954, then

$$X = X_e + X_w,$$

and

$$x = x_e\frac{X_e}{X} + \frac{X_w}{X}$$

$$= 0.9x_e + 0.1x_w.$$

If we let x vary, the second expression describes a family of straight lines in an (x_e, x_w) plane, four of which are shown in Figure 1. Each line is a locus of points the coordinates of which give the percentage cuts in acreage in the two regions that will yield a given reduction nationally. Thus, a 40-percent reduction nationally may be obtained by cuts of 45 percent in the East and zero in the West, or 33 percent in the East and 100 percent in the West, or any combination meeting the above restrictions. Lines further from the origin indicate larger reductions. There is only one set of regional reductions that will leave unchanged the distribution of the national allotment between the two regions: the one in which each region is reduced by the same proportion, depicted in Figure 1 by a 45-degree line from the origin. At points above this line, the West will be reduced proportionately more than the East, so that its share of national acreage will be less after the change than before. For points below the 45-degree line, of course, the East would suffer a decline in share.

With no change in the existing law, the national acreage in 1954 would have been reduced about 35 percent from 1952; the regional reductions would have been 33 percent in the East and 51 percent in the West. Point A in Figure 1 shows this situation; its distance above the 45-degree line indicates the disproportionately large acreage reduction borne by the West. The bargaining problem was to find a point that both East and West preferred over staying at Point A. The West made the first offer, moving to Point B. This offer was hardly taken seriously by the southern contingent; it allowed too large a reduction in the national acreage, thereby posing the danger that allotments might be suspended the year after. Furthermore, it did not conform enough to their preferences on how the reduction should be distributed among regions, since it reduced acreage in the West by the same proportion as that in the East. A second western proposal was then made to Point C. This would have allowed a smaller reduction in national acreage and, since it was slightly above the 45-degree line, implied that the West would bear a somewhat more than proportionate amount of the reduction.

At this time the eastern interests made their first specific offer—Point E. It represented about the same national acreage cut as was contained in the second western offer but involved a somewhat greater disproportion

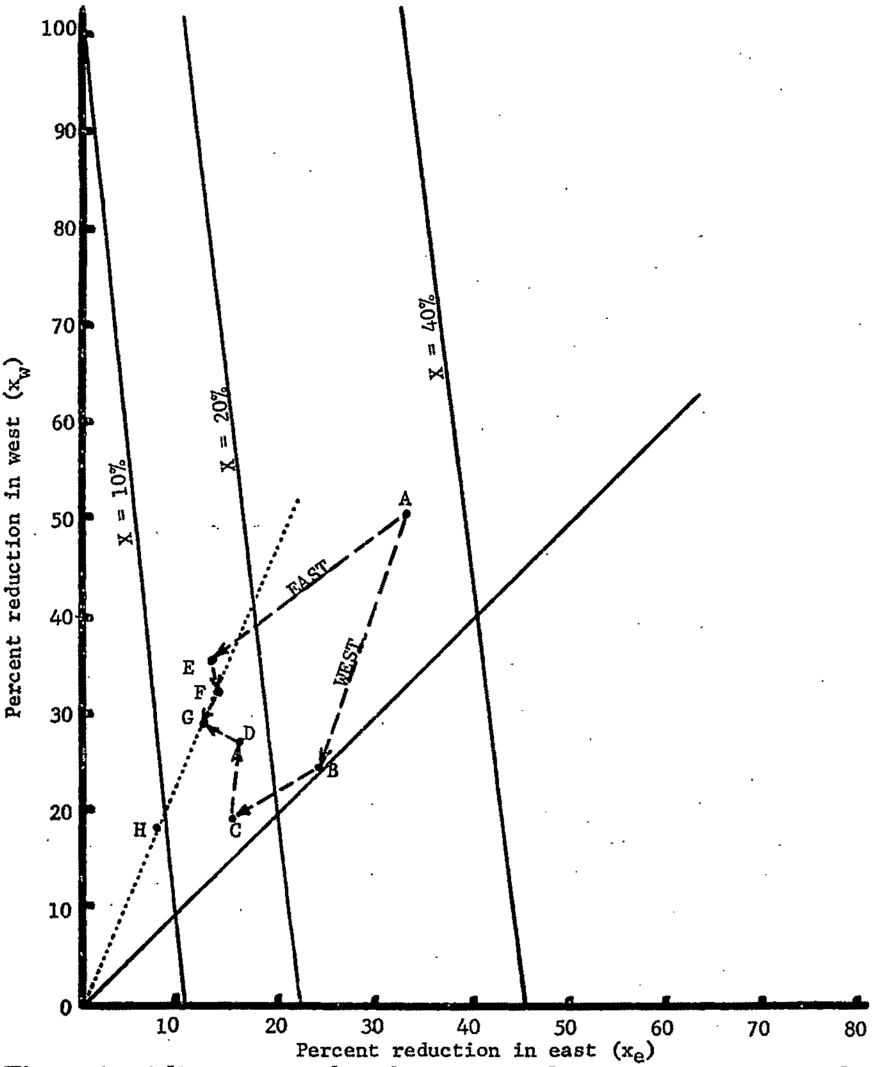

Figure 1. Adjustment paths of eastern and western interests in the 1953 acreage bargaining
Source: Table 2.

in the regional reductions than Point *A*. At the latter, the percentage reduction in the West would have been approximately 1.4 times that of the East, while at Point *E* the western reduction would have been about 2.8 times that of the East. This first eastern offer, although lessening the amount by which the allotment for the West would be reduced (from 51 percent to 36 percent), involved no move toward the 45-degree line, indicating that in the second year the western share of the national acreage

would be substantially reduced. The West then moved to Point D; this move was followed by a move of the East to Point F. The final agreed-upon position was Point G, representing a compromise between the two groups in terms of the regional distribution of the acreage reduction.

We may interpret this bargaining process in terms of the conclusions drawn previously on the distribution of power between the eastern and western cotton interests. We assume that the East had the power of policy initiative, and of manipulating the policy within the "negotiation set," that is, the set of all mutually preferred alternatives. The West, by virtue of external constraints on committee agreements, had power to veto formulas that were not preferred to the status quo but had little power beyond this. The East, then, was motivated to bargain in such a way that the policy finally agreed upon would be just preferred by the West to the status quo, Point A. In this case the final policy can be considered as representing the next most preferred position for the West above the "no change" alternative.[11] In moving to this position, the West paid a cost in the form of reduced probability that acreage allotments would be discontinued in the near future, because the point of agreement represented a substantially smaller short-run reduction in the 1954 allotment than did Point A, the status quo alternative. In return for this, the West secured benefit in the form of a reduction in the amount by which its acreage would be cut back, from 51 percent to 29 percent. Evidently, then, the compensation to the West of 22 percent of its acreage was sufficient to pay for the reduction in probability of having "free" planting in the near future and still leave the West in a marginally preferred position.

There is no way of telling by how much Point G exceeds the reservation preference of the eastern interests—the alternatives they would have just preferred to the status quo. However, by interpreting Point E as the East's most preferred alternative—that is, the alternative which it would have chosen had there been no need of bargaining with the West—we can measure the amount by which the East had to retreat from this position in order to induce the cooperation of the West.[12] At Point E the West would have been cut 36 percent from its 1952 acreage; at Point G the West would have been cut only 29 percent, a reduction of 7 percentage points. In addition, the "payment" to the West existed in the form of a relatively larger share of the national acreage in the following year. At Point E the West's share in 1954 would have been 6.4 percent, whereas at Point G it was 7.2 percent, an increase of 0.8 percentage points. Thus, in order to secure the cooperation of the West, the East had to add back onto its ori-

[11] The West's complete preference ordering of the points on Figure 1 might reasonably be expected to have been B, C, D, G, A, F, and E.

[12] The main problem with this assumption is that the East's first proposal, Point E, was made after the West had made several proposals.

ginal offer about 164,000 acres of the western reduction and 0.8 percentage points of the share in national acreage.

We do not have the necessary data to depict the bargaining process that took place in 1949.[13] We can, however, show the final outcome reached that year. This is represented by Point *H* in Figure 1, and shows a reduction in the West of about 19 percent and in the East of about 8 percent. It is interesting to note that the final outcomes in 1949 and 1953 lie approximately on a straight line starting from the origin. Any straight line of this sort is a locus of points in which the ratio of percentage reductions in the East and West is constant. The line connecting the 1949 and 1953 policies implies a ratio of approximately 2:1; thus, anywhere on this line the percentage reduction in the West will be about twice that of the East. This could be taken, perhaps, as an index of the distribution of congressional power between East and West; its occurrence in two different bargaining episodes suggests a relatively high degree of stability in the political interactions of regional cotton interests in Congress. Admittedly, the bargaining depicted here involved very explicit "payoff" units—acres of cotten allotment—which is often not the case with legislative action in Congress. It is considerably more difficult to describe the bargaining that takes place on measures for which the social implications are themselves obscure.

Conflict over the regional allocation of acreage subsided somewhat after the events of 1949 and 1953-54. Conflicts concerning permanent allotment rights gave way after this to bargaining on special producer option plans—allowing producers to choose different combinations of price support and proportion of allotment planted. One may speculate on the strength of the shock it would take to upset this policy status quo: whether, for example, a relatively large increase in the national allotment would lead to attempts by the two regions to improve their relative positions, as happened among sugar producers in recent years. Investigation here, however, must wait upon the necessary changes in the national supply situation.

References

[1] BLOCK, WILLIAM J., "Reapportionment and Its Implications," in *Increasing Understanding of Public Problems and Policies,* Chicago, Farm Foundation, 1965, pp. 111–120.

[2] BUCHANAN, JAMES M., AND GORDON TULLOCK, *The Calculus of Consent,* Ann Arbor, University of Michigan Press, 1962.

[13] The formula distributing the national allotment for the 1950 program originated in an ad hoc meeting among producer groups in Memphis early in 1949. It was written into law with few changes. This agreement among producer groups seems to have been reached in an atmosphere similar to that existing in Congress, a necessary condition, perhaps, if legislators were to be convinced that the compromise was a "real" one, that is, not biased regionally any more than the comparable congressional action would have been [21, pp. 43–46].

[3] COLEMAN, J. S. "The Possibility of a Social Welfare Function," *Am. Econ. Rev.* 61:1106–22, Dec. 1966.
[4] DAHL, ROBERT A., AND CHARLES E. LINDBLOM, *Politics, Economics, and Welfare,* New York, Harper & Row, Publishers, Inc., 1953.
[5] FENNO, RICHARD F. JR., "The Appropriations Committee as a Political System," *Am. Pol. Sci. Rev.* 56:315–330, June 1962.
[6] ———, *The Power of the Purse,* Boston, Little, Brown and Co., 1966.
[7] FIELD, BARRY C., "The Impact of Changing Economic Structure on the Strategy of Agricultural Policy: The Case of Cotton," unpublished Ph.D. thesis, University of California, 1967.
[8] GLLO, P. S., AND C. MCCLINTOCK, "Cooperative and Competitive Behavior in Mixed Motive Games," *J. Conflict Resolution* 9:68–78, March 1965.
[9] HATHAWAY, DALE E., *Government and Agriculture,* New York, The MacMillan Company, 1963.
[10] HEINZ, JOHN P., "The Political Impasse in Farm Support Legislation," *Yale Law J.* 71:952–978, April 1962.
[11] JONES, CHARLES O., "Representation in Congress: The Case of the House Agriculture Committee," *Am. Pol. Sci. Rev.* 55:358–367, June 1961.
[12] ———, "The Role of the Congressional Subcommittee," *Midwest J. Pol. Sci.* 6:327–344, Nov. 1962.
[13] MANLEY, JOHN F., "The House Committee on Ways and Means: Conflict Management in a Congressional Committee," *Am. Pol. Sci. Rev.* 59:930–944, Dec. 1965
[14] MATTHEWS, DONALD R., *U.S. Senators and Their World,* Chapel Hill, University of North Carolina Press, 1960.
[15] MUNGER, FRANK J., AND RICHARD F. FENNO, JR., *National Politics and Federal Aid to Education,* Syracuse, Syracuse University Press, 1962.
[16] RICE, STUART A., "Measuring Cohesion in Legislative Groups," in *Legislative Behavior,* ed. John C. Wahlke and Heinz Eulau, Glencoe, Ill., The Free Press, 1959, pp. 372–377.
[17] ROTHENBERG, JEROME, *The Measurement of Social Welfare,* Englewood Cliffs, N.J., Prentice-Hall, Inc., 1961.
[18] SCHELLING, THOMAS C., *The Strategy of Conflict,* New York, Oxford University Press, 1963.
[19] TRUMAN, DAVID B., *The Governmental Process,* New York, Alfred A. Knopf, Inc., 1962.
[20] U.S., Congress, House, Subcommittee on Cotton of the Committee on Agriculture, *Hearings, Cotton Programs,* Serial RR, 81st Cong., 2d Sess., 1949.
[21] U.S., Congress, Senate, Subcommittee of the Committee on Agriculture and Forestry, *Hearings, Cotton Marketing Quotas and Acreage Allotments,* 81st Cong., 1st Sess., 1949.
[22] U.S., *Congressional Record,* 81st Cong., 2d Sess., 1950, Vol. 96, Part 1.
[23] U.S., *Congressional Record,* 81st Cong., 2d Sess., 1950, Vol. 96, Part 2.
[24] U.S., *Congressional Record,* 83rd Cong., 1st Sess., 1953, Vol. 99, Part 8.
[25] U.S., *Congressional Record,* 83rd Cong., 2d Sess., 1954, Vol. 100, Part 1.
[26] WALTON, RICHARD E., AND ROBERT B. MCKERSIE, "Behavioral Dilemmas in Mixed-Motive Decision Making," *Behavioral Sci.* 11:370–384, Sept. 1966.
[27] WILDAVSKY, AARON, *The Politics of the Budgetary Process,* Boston, Little, Brown and Co., 1964.

Estimating the Productivity of Agricultural Pesticides*

J. C. HEADLEY

The controversy surrounding the use of agricultural pesticides has resulted in the examination of pest control technology and a need for estimates of the costs and benefits of pesticides. Estimates of the productivity of expenditures for agricultural pesticides are made from an aggregate production function analysis for 1963. The results indicate that chemical pesticides are a highly productive input, comparable to commercial fertilizer, and that the marginal value product of pesticides exceeds marginal factor cost by a considerable amount. These results are consistent with increasing sales volumes of pesticides and fertilizer nationally. Use of values determined through the market system to estimate benefits are a necessary part of evaluating chemical pest control. Up to the present time, no systematic effort has been made to estimate separately the productivity of pesticides. The findings point to a need for better data on the response of crops and livestock to pest control as well as a need for data on the external effects of chemical pesticides. Considerably more analysis and information are required to evaluate pesticide technology and to form good national policy in this area.

CHEMICAL pesticides are widely used in North American agriculture to control insects, nematodes, fungi, and weeds. They can be applied to crops before planting, during growth, and in storage. U.S. farmers spent an estimated $310 million in 1961 for pesticide materials exclusive of application costs, and expenditures have been increasing, as evidenced by estimated expenditures of $514 million in 1964 [1].

Not only has there been a dramatic increase in the quantity of pesticides used in the last two decades, but the diversity of materials used as well as the types of uses has increased. Before 1800, simple compounds such as lye, lime, soap, turpentine, mineral oil, and arsenic were used as insecticides. The use of Paris green in 1867 to control the Colorado beetle marked the beginning of the use of commercial pesticides and led to the commercial use of lead and calcium arsenate. Before 1945 and the introduction of DDT, the use of agricultural insecticides was confined to fruits, vegetables, cotton, and a few other high-value crops [4].

With the introduction of the new synthetic organic pesticides, including the chlorinated hydrocarbons, the organic phosphates, and the carbamates, pesticides are now used to protect field crops, pastures, and forests. Sales of synethic organic pesticides for all uses increased from 279

* The research on which this article is based was conducted while I was on leave from the University of Illinois as a visiting scholar at Resources for the Future, Inc., Washington, D.C. I am grateful for helpful suggestions made by Oscar R. Burt during preparation of the manuscript.

J. C. HEADLEY *is associate professor of agricultural economics at the University of Missouri.*

million pounds in 1954 to about 634 million pounds in 1962 [13]. Sales of herbicides have increased more rapidly than sales of either insecticides or fungicides.

About 5 percent of the land area in the United States is treated with insecticides annually. More than three-fourths of the treated area is cropland or cropland pasture, with nearly one-half of the treated cropland planted to grain. However, only 15 percent of the grain acreage is treated, whereas 30 percent of the fruit and nut acreage, 75 percent of the cotton acreage, and 50 percent of the vegetable acreage are treated annually (figures based on estimates made for 1962). The land area treated with herbicides in 1962 was estimated at more than 85 million acres and represented a 60-percent increase over 1959. Since there is considerable overlap of land treated with insecticides and land treated with herbicides, it has been estimated that 1 acre in 12 of the nation's total land area receives one or more pesticide treatments each year [15]. Of all pesticides sold by United States firms in 1964, about 40 percent were sold to farmers. Industry, government, home owners, and exports accounted for the rest. If only sales for domestic use are considered, farmers accounted for a larger proportion of pesticide sales, since exports were sizable.

Wide use of chemicals to control pests, reports of such adverse effects resulting from their use as the killing of fish and other wildlife, and the discovery of DDT and its metabolites in the adipose tissue of humans and other warm-blooded animals have been responsible for controversy over the use of pesticides. Considerable research has been directed toward reducing uncertainty about externalities associated with pesticides.[1] In addition, some research has been directed toward the development of policy at the national level [4]. Pest control policy should attempt to bring the social costs of pesticide use into balance with the benefits by providing guidelines for research investment, by regulating the use of chemicals and other kinds of pest control, and by establishing institutions for dealing with pest control problems.

Objectives and Procedures

The objective of this study is to estimate the contribution of pesticide expenditures to agricultural output as a partial measure of the benefits of pesticide use. Such estimates provide part of the information needed to determine whether the net social benefits from the use of pesticides diverge significantly from the optimum and, therefore, whether major changes in pest control policy are needed.

Production functions were estimated by using state data from the

[1] For discussion of externalities and application to problems of quality, common property resources, and outdoor recreation, see Castle [2]. For a specific discussion of externalities applied to pesticides, see Headley and Lewis [4].

USDA farm income and expense series for the year 1963. The state data were treated in two ways. First, data for states were divided by the estimated number of farms in each state to develop input–output data for the average farm. These data were used with a Cobb–Douglas function to estimate production elasticities for the inputs and to compute marginal products. Second, the state data were divided by the estimated total acreage devoted to 59 principal crops harvested in each state. These data represent input and output per crop acre for each state in 1963 and were used with a function which provided weights for the input variables through use of an iterative procedure and then fitted a third-degree polynomial to the weighted sum of the inputs.[2] The variables used and specific sources of data are given in the Appendix.

Estimated parameters of the Cobb–Douglas functions are interpreted as partial production elasticities of the input variables [5]. Since the measure of output used was in value terms, partial differentiation of the production function with respect to the various inputs provides an estimate of the marginal value products of the inputs. The estimate of the marginal value product of expenditure for pesticides can be compared to its marginal factor cost to determine the extent of disequilibrium in the use of pesticides by farmers and can also be used to estimate the aggregate benefits from pesticides, given the level of farm prices that prevailed in 1963.

Estimates of production elasticities were obtained for Cobb–Douglas equations containing various formulations of the input variables for the 48 states. The different formulations were used in an attempt to overcome the difficulty of interpreting estimated partial regression coefficients resulting from high simple correlations between certain input variables. The same problem has arisen in previous studies, for example, in Ruttan [7]. Table 1 presents the matrix of simple correlation coefficients for the logarithms of the variables used, computed from the per-farm data.

Since the focus of this study is on the contribution of pesticides to agricultural production, the fact that the variable measuring the total labor input is highly correlated ($r = 0.77$) with the variable measuring pesticide expenditures is a source of difficulty. Variables measuring land and buildings, machinery, and other miscellaneous inputs are also strongly correlated with each other, but the parameters for these variables are of minor interest.

Various techniques for dealing with this input complementarity were used. One technique involved combining variables where they were ex-

[2] This functional formulation was suggested by Oscar R. Burt. The polynomial that was fitted by least squares was of the form $Y = a + b_1U + b_2U^2 + b_3U^3$, where $U = w_1X_1 + w_2X_2 + \cdots + w_mX_m$. The variables $X_1, \ldots, X_m$ are input variables, and the parameters $w_1, \ldots, w_m$ are weights estimated by an iterative procedure.

Table 1. Matrix of simple correlation coefficients for variables used in production function for U.S. agriculture, 1963[a]

Variable[b]	Output	Total labor	Land & buildings	Machinery	"Other"	Fertilizer	Pesticides	Machinery plus "other"
Output	1.00	0.69	0.88	0.83	0.91	0.57	0.53	0.94
Total labor		1.00	0.62	0.40	0.59	0.52	0.77	0.58
Land & buildings			1.00	0.83	0.75	0.41	0.39	0.80
Machinery				1.00	0.76	0.21	0.21	0.86
Other					1.00	0.45	0.44	0.98
Fertilizer						1.00	0.50	0.42
Pesticides							1.00	0.42
Machinery plus "other"								1.00

[a] The unit of observation was the average farm in each state. The number of observations is thus 48. Correlations represent the degree of linear association between the logarithms of the variables.
[b] See Appendix for definition of variables.

pressed in the same units, such as dollars. This technique was used with machinery and "other" inputs. Another technique was to develop an index of sets of related variables through use of principal-component analysis and to insert the index into the regression equation as a proxy for the original variables. To construct this index, I first extracted the largest root of the correlation matrix of the related variables. I then computed weights for each variable in the set and used them to construct an index variable to act as a proxy for the entire set [16].

Limitations of the Data and Technique

The data and procedure are subject to several limitations.

1. The data are per-farm averages for each state and, therefore, much of the variation in input and output has been lost in aggregation.

2. Use of an aggregate production function assumes homogeneity in the technology used throughout the nation. Therefore, the use of the function parameters for individual decisions is not valid.

3. Because the variable measuring pesticide input is expenditure, it is assumed that this expenditure is a good proxy for the input of the particular chemicals used. Obviously, the productivity of a chemical will vary widely and will depend on the crop grown, the pest attacked, and the amount and timing of the application.

4. The pesticide expenditure data were generated from a 1955 base estimate, and a time series was developed based on relationships that existed in 1955. Therefore, the variance between states may not be accurately estimated for 1963. However, these were the only data available for measuring pesticide inputs. Better estimates will be available when the USDA completes analysis of surveys conducted in 1965 and 1967.

5. Interpretation of the regression coefficients and estimation of the partial effects of the variables is hampered by strong complementarities between certain input variables.

Production Function Estimates

Production elasticities derived are given in Table 2. The equations give alternative estimates of the agricultural production function for the nation.

Table 2. Production elasticities of inputs estimated with different formulations for the United States, 1963

Variables	Regression equations[a]			
	1	2	3	4[b]
Total labor	0.0854 (0.1272)	0.0554 (0.1236)	0.1517 (0.0487)	0.1766
Land and buildings	0.1930 (0.0529)	0.2540 (0.0425)	0.1845 (0.0503)	0.2568
Machinery	0.3148 (0.0743)	—	0.3178 (0.0735)	0.0303
"Other"	0.2827 (0.0402)	—	0.2818 (0.0398)	0.3375
Fertilizer	0.1656 (0.0342)	0.1415 (0.0326)	0.1663 (0.0339)	0.1578
Pesticides	0.0552 (0.0288)	0.0413 (0.0285)	0.0406 (0.0130)	0.0605
Machinery plus "other"	—	0.5010 (0.0425)	—	—
Total elasticity	1.10	0.99	1.14	1.02
R^2	0.9647	0.9644	0.9644	0.9863

[a] Equations 1 to 3 are Cobb–Douglas and equation 4 is a third-degree polynomial.
[b] Since these elasticities were computed at the mean for the third-degree polynomial and were not derived directly from regression, standard errors for the elasticities are not available.

Equations 1 to 3 are Cobb–Douglas functions. Equation 1, using the average input and output per farm in each state as observations, gives partial production-elasticity estimates for six input variables. Equation 2 differs from equation 1 in that the variables measuring machinery inputs and "other" expenses were arithmetically summed and a coefficient was estimated for the combined effect of the two inputs. Equation 3 is the same as equation 1 except that a single index representing both labor and pesticides was constructed and was used as a proxy for these two categories of inputs. Elasticities for labor and pesticides were computed from the estimated coefficient for the index variable. The observations for equation 4 were input and output per acre of 59 principal crops grown in each state in 1963.

In equations 1 and 2, the partial regression coefficient for labor was smaller than its standard error in both cases. Standard errors for the other variables were smaller than their respective coefficients. Both of these equations show the effects of multicollinearity on the estimated parameters of the labor and pesticide variables. It is believed that the coefficient for labor was reduced and that the coefficient for pesticides was inflated because of multicollinearity.

The variable representing machinery inputs and the variable representing "other" expenses were summed to form one composite variable in equation 2. The simple correlation of this composite variable with other variables in the analysis is given in Table 1. Use of this combined variable reduced the regression coefficients for the labor, fertilizer, and pesticides variables, but increased the coefficient for land and buildings. The regression coefficient for the combined variable in equation 2 was less than the sum of the separate coefficients of machinery and "other" in equation 1. The sum of the coefficients was reduced from 1.10 in equation 1 to 0.99 in equation 2.

Estimates of the production elasticities given by equation 3 show the effects of using an index variable as a proxy for both labor and pesticides. The effect of this substitution was to leave the estimated elasticities for land and buildings, machinery, "other," and fertilizer virtually unchanged relative to equation 1. However, the elasticity derived for labor increased and that for pesticides decreased, and the computed standard errors for both coefficients declined compared to those in equation 1. This equation seems the most plausible of the three equations estimated by using the average farm as the unit of observation. The index variable representing labor and pesticides accounted for 88.5 percent of the variation in the two variables.

In Table 2, the elasticities shown under equation 4 were derived from an equation fitted to data which represented the input and output for each state in 1963 divided by the acreage devoted to 59 principal crops in 1963. They are therefore based on an average crop acre rather than an average farm. These elasticities were computed at the arithmetic means from a function that did not display constant partial elasticities for the inputs.

Results obtained by using the average crop acre as the unit of observation correspond, with the exception of the elasticity for the machinery variable, to those obtained by using the average farm as the unit of observation. The elasticity for machinery in equation 4 is much smaller than any of the coefficients estimated for this variable in the other equations. When the state data were divided by the total acreage devoted to 59 principal crops, the intercorrelations between machinery, land and buildings, and "other" expenses increased compared to those shown in Table 1. There-

fore, the machinery production elasticity may be underestimated and perhaps the coefficients for land and buildings and "other" expenses may be overestimated. The elasticities for labor, fertilizer, and pesticides in equation 4 were very similar to the estimated elasticities for these inputs in equation 3. The results of equation 4, because they were obtained with a different functional form and based on a different transformation of the data, lend support to the results of equation 3.

Marginal Productivity Estimates

In Table 3, the estimates of the marginal productivity of the inputs are shown for each of the four equations used. The problems discussed earlier, due to intercorrelation among the inputs, are evident in the marginal product estimates for the inputs.

Table 3. Marginal products of farm inputs in U.S. agriculture, 1963

Variables	Regression equations			
	1	2	3	4
Total labor	$2.16/day	$1.40/day	$3.84/day	$4.21/day
Land and buildings	0.06/$1.00	0.08/$1.00	0.06/$1.00	0.08/$1.00
Machinery	2.40/$1.00	—	2.43/$1.00	0.26/$1.00
"Other"	0.97/$1.00	—	0.97/$1.00	1.07/$1.00
Fertilizer	4.91/$1.00	4.20/$1.00	4.50/$1.00	3.95/$1.00
Pesticides	5.66/$1.00	4.23/$1.00	4.16/$1.00	3.90/$1.00
Machinery plus "other"	—	1.16/$1.00	—	—

It was stated earlier that the results of equation 3 seemed more plausible than those of equations 1 and 2. The marginal products shown for equation 3 are more in line with "reasonable" values. With the exception of machinery, the marginal products provided by equation 4 are similar in magnitude to those in equation 3.

Results from all of the equations suggest that the productivity of an additional dollar spent for fertilizer and pesticides at their mean levels is approximately the same. All equations suggest that the marginal product of labor is below the 1963 wage rate in most areas and that the marginal product of land and building capital is close to the market rate of interest. It is possible, however, that, because of intercorrelation, the marginal product of land and building investment reflects some of the effect of machinery and "other" expenses.

Marginal products of fertilizer and pesticide expenditures of the magni-

tude shown in Table 3 suggest that the markets for these factors are in disequilibrium on a national basis.[8] This conclusion is consistent with a national trend of increasing sales of both fertilizer and pesticides. The estimate of from $3.95 to $4.91 per dollar of fertilizer is similar to results obtained by Griliches [3], Ibach and Lindberg [6], Ruttan [7], and others in previous studies.

Naturally, any conculsions based on this aggregative analysis as to the state of disequilibrium in the factor markets may not apply to local situations. However, the findings do suggest that when only the values which are determined in the market are considered benefits could be increased by applying more pesticide materials in agriculture.

Reference was made earlier to the low marginal contributions of labor in all of the equations. Values obtained were considerably less than the daily wage rate estimated by the USDA in 1963 [9, p. 6]. They were also below the value obtained by Griliches for 1959 [3]. However, the continued out-migration from farming and rural areas is not inconsistent with a marginal contribution of labor which is less than the prevailing wage rate.

The marginal rates of substitution of pesticides for nonpesticide inputs implied by this study (see Table 3) tend to be high for all inputs except fertilizer. However, these sates do not reflect constant pest population and therefore should not be given too much significance. Further research needs to consider the level of pest populations in relation to alternate forms of pest control.

Estimates of the marginal value of pesticide expenditures of the magnitude suggested in this study may be distressing to some, especially to those who believe that the costs imposed by chemical pesticides on society outside the food and fiber market are large and that therefore the amount of chemicals used to control pests should be reduced. The results obtained in this study are not in conflict with this position, but neither do they support the position of those who argue that because pesticides are highly productive their use should go on unaltered and unabated. Just as the marginal value of labor can be interpreted as the marginal value of energy, so the marginal value of chemical pesticides expresses the marginal value of pest control. The estimates developed by this study indicate the value of controlling crop pests. Any method of pest control that gave comparable results would be judged as equally productive.

Benefits from Pesticides

In 1963, U.S. farmers spent an estimated $436 million for pesticide chemicals used in crop production. If the estimate developed in this study

[8] The criterion for equilibrium is the equating of the marginal value product of an input to its marginal factor cost. In the case of fertilizer and pesticides in this study, marginal factor cost equals $1.00.

of the marginal value productivity of these expenditures (Table 3, equation 3) is interpreted as an average value, an estimate of the total benefits from pest control of about $1.8 billion is obtained. This represents about 4.5 percent of realized gross farm income or about 10.5 percent of cash receipts from crops in 1963.

Although the estimates developed in this study are crude and subject to severe limitations, they provide, as a beginning, some criteria for judging the performance of pest control methods that are alternative to chemicals. The estimates were systematically derived, with account taken of the influence of other inputs in the production process, and represent the results of aggregate behavior in U.S. agriculture. They are not extrapolations from a limited number of isolated experiments. Hence, they provide a starting point for the assessment of benefits from pest control.

These estimates and subsequent ones (which, we may hope, will be better) can be useful in guiding research and developing pest control policy. If an alternative pest control method has the same resource requirement as a chemical or set of chemicals and is as productive as the chemical or chemicals which it will replace, the justification for development of the alternative method then rests on its reduction of external costs. With a reasonable interest rate, the annual interest charge on the research investment will be equal to or less than the present value of the external costs eliminated. If any losses in productivity are experienced, their discounted value must be added to the research costs.

In fiscal year 1965, about $29 million was appropriated to the U.S. Department of Agriculture for pest control research. Use of these funds to develop alternatives to chemical pest control and/or "clean" chemicals designed to be as effective as the chemicals now used would imply reductions in external costs required by the criteria described above. At an interest rate of 6 percent, at least $1.74 million of external costs would need to be eliminated annually to perpetuity.

Conclusions

Results of this study indicate that the marginal value of a one-dollar expenditure for chemical pesticides is approximately $4.00. This apparent national disequilibrium in pesticide use is consistent with the expanding market for these materials. If the marginal product is interpreted as an average value, it implies annual benefits of about $1.8 billion attributable to chemical pesticides used on crops.

The estimated productivities can be used to evaluate and compare the economic efficiency of chemical pesticides and alternate forms of pest control. The productivity estimates of current techniques of pest control provide a base for measuring the costs of and/or benefits from alternative methods. Combination of this information with the effects of alternative

methods on external costs and/or benefits provides the data necessary for computing the net social costs and benefits of the various techniques of pest control.

Appendix

Definitions of Variables and Data Sources

The variables used in this study apply to the 48 conterminous states of the United States.

Output is the value of all cash marketings by farmers, plus government payments, plus the value of home consumption, adjusted for inventory changes [10].

Total labor is days of labor input by farm operators, family, and hired labor. The total labor input in days per farm was calculated by a formula used by Griliches [3], namely

$$D\{N\,(1 \;-\; 0.4A) + 0.65\,(F - N)\} + HE/W,$$

where

D is the days of operator labor, assumed equal to 300 minus the average number of days worked off the farm [14];

N is the number of farms, assumed equal to the number of operators [12];

A is the fraction of farm operators over the age of 65 years in 1959 [14];

F is the number of family workers [14] and includes operators;

$F - N$ is the estimated number of unpaid family workers;

HE is the total expenditure for hired labor in 1963 [10];

W is the average daily wage rate, without room and board, given by states for 1963 [9]; and

HE/W is the estimated days of hired labor input.

The fractions 0.4 and 0.65 are assumed parameters to reflect the quality of older farm operators and unpaid family workers, respectively.

Land and buildings is a capital stock variable and is the estimated value of land and buildings on farms in 1964 [11].

Machinery is the value of depreciation, repairs, and direct costs of operation of machinery on farms, including the cost of petroleum products (unpublished USDA data).

Other expenditures are those for purchased feed, livestock, seed, and miscellaneous items [10], plus 8 percent of the January 1, 1963, inventory value of livestock on farms [8].

Fertilizer is the expenditure for commercial fertilizer, limestone, and rock phosphate, excluding slag, sludge, and barnyard manure [10].

Pesticides is the expenditure by farmers for chemical pesticide materials used on crops and does not include costs of application (unpublished USDA data).

Machinery and "other" is the simple sum of expenditures for machinery plus expenditures for inputs classified under "other."

The data for each variable were obtained as state totals and were divided by the estimated number of farms in 1963 to provide per-farm estimates for each state. These per-farm estimates were used as observations in the Cobb–Douglas functions. The state totals were also divided by the total acreage devoted to 59 principal crops harvested in each state [8]. The per-acre estimates were used as observations in the function which fitted a polynominal to the weighted linear sum of the inputs.

References

[1] ANDRILENAS, PAUL, THEODORE EICHERS, AND AUSTIN FOX, *Farmers Expenditures for Pesticides in 1964,* USDA ERS Agr. Econ. Rep. 106, Jan. 1967.

[2] CASTLE, EMERY N., "The Market Mechanism, Externalities and Land Economics," *J. Farm Econ.* 47:542–556, Aug. 1965.

[3] GRILICHES, ZVI, "Research Expenditures, Education, and the Aggregate Agricultural Production Function," *Am. Econ. Rev.* 54:961–974, Dec. 1964.

[4] HEADLEY, J. C., AND J. N. LEWIS, *The Pesticide Problem: An Economic Approach to Public Policy,* Washington, Resources for the Future, Inc., 1967.

[5] HEADY, EARL O., "Relationship of Scale Analysis to Productivity Analysis," in *Resource Productivity Returns to Scale and Farm Size,* ed. Earl O. Heady, Glenn L. Johnson, and Lowell S. Hardin, Ames, Iowa State College Press, 1956, pp. 82–89.

[6] IBACH, D. B., AND R. C. LINDBERG, *The Economic Position of Fertilizer Use in the United States,* USDA Info. Bul. 202, 1958.

[7] RUTTAN, VERNON W., *The Economic Demand for Irrigated Acreage,* Baltimore, The Johns Hopkins Press, 1964.

[8] U.S. Department of Agriculture, *Agricultural Statistics,* 1965.

[9] ———, SRS, Crop Reporting Board Release, *Farm Labor,* La 1 (1–65), Jan. 11, 1965.

[10] ———, *Farm Income Situation,* ERS FIS-199 Supplement, Aug. 1965.

[11] ———, ERS, *Farm Real Estate Developments,* CD-64, Aug. 1963.

[12] ———, SRS, Crop Reporting Board, *Number of Farms and Land in Farms,* SpSy (1–65), Jan. 1965.

[13] ———, ASCS, *The Pesticide Situation for 1962-63,* Sept. 1963.

[14] U.S., Department of Commerce, *The 1959 Census of Agriculture,* Vol. 2, 1962.

[15] U.S., Department of Interior, *Pesticide–Wildlife Studies,* Fish and Wildlife Circ. 167, June 1963.

[16] WAUGH, FREDERICK V., "Factor Analysis: Some Basic Principles and an Application," *Agr. Econ. Res.* 14:77–80, Aug. 1962.

Allowing for Weather Risk in Assessing Harvest Machinery Capacity

G. F. DONALDSON

To take account of the effect of weather on the cereal harvest, a simulation model is outlined in which rates of combine work, harvest weather, and diurnal grain-moisture content are regarded as probabilistic, with known distributions based on empirical data. On the basis of this data, the interaction of the variables is assessed over a thousand "years" of synthetic harvesting experience, in which the timeliness of the harvesting operation is assessed in terms of increased grain drying costs, and which is repeated to assess various policies which might be adopted by farmers. The results are presented as normative average total cost curves for various harvesting systems, based on the certainty equivalence of the decision under risk.

WEATHER impinges upon many aspects of agricultural production. Most directly, it affects the various physical operations in the farming year, restricting both the time available for specific tasks and the efficiency with which they can be completed. These effects are not restricted to agriculture, for they clearly influence the operations of other industries, notably those of building and construction work. Pertaining more directly to agriculture, however, are the characteristic biological effects of various weather ingredients, which indirectly also influence physical operations.

Thus, in agriculture, weather significantly increases the spectrum of uncertainties which render decision making so complex. Its interference with day-to-day operations can cause wide fluctuations in annual costs, and its determining role in biological processes can greatly influence yields and consequently cause marked variations in annual gross revenue. Such variations will affect the fortunes of individual farms and, in aggregate, those of whole industries. In view of this fact, it is not surprising that agricultural research workers have extensively investigated the climatic variables surrounding agricultural production. There is consequently a large body of published work dealing with various aspects of weather as it affects plant and animal husbandy.[1]

Similarly, farm economists have sought to take account of variations associated with uncertain weather in the analysis of farm decisions. In general, this attempt has been less successful, because of the large number of variables involved, the lack of accurate measurements, and the limitations of analytical and computational facilities. Recently, there has been renewed interest in taking account of meteorological measurements and

[1] A bibliography of new work in all aspects of this field is published quarterly in the journal *Agricultural Meteorology* (Elsevier: Amsterdam).

G. F. DONALDSON *is lecturer in agricultural economics at Wye College (University of London).*

weather expectations when analyzing farm management problems. Some analytical approaches which might be used when assessing the impact of weather on overall farm programs have been formulated; they use such techniques as quadratic programming, simulation, and "maximin programming" [7, 8, 9, 15]. Of more specific interest, the relationship between weather and new technology in determining enterprise output has been explored in studies which have considered time series of yields and weather variables, using regression analysis and an aridity-index approach [11, 12, 13]. The impact of weather on physical operations in farm production has also been studied, most notably by McQuigg and Doll, who applied a model of weather expectations in assessing the need for grain-drying equipment [10].

The work in these last two categories is significant in that it gives recognition to the relationship between reduced production uncertainty and new technology. A primary effect of technological innovation in agriculture is the removal of some of the uncertainty from farm production. This may be achieved through less variability in yields, due to improved crop varieties or better fertilizers; through more reliable production resulting from the control of plant and animal environments by irrigation and housing; or through the expediting of physical operations by the use of better farm machinery. The technological innovations which permit this reduction of uncertainty, however, all require capital. Biological innovations such as new varieties, herbicides, or fertilizers involve only small increases in working capital, but new machinery and fixed equipment may involve large increases in fixed or short-run investment. Because of this relationship between capital-requiring innovations and production certainty, an evaluation of investment in new technology cannot be made without some assessment of the variability which the investment will reduce.

Recognizing this, Duckham has suggested a special role for agricultural meteorology in capital investment decisions on farms [4, pp. 323–375; 5, p. 7]. Using examples from Sonning Farm of Reading University, Duckham has emphasized the feasibility of his suggestion by outlining some elementary decision models which take account of the variability due to weather which is inherent in different types of farm investment decisions. Recognized limitations on the use of these models are both the lack of recorded data on the variables which need to be quantified and the shortage of procedures for resolving the problems embodied in the models.

In this article I will discuss one method of solving these problems. I will analyze a farm management decision on the optimum capacity system (and hence the optimum level of investment) for harvesting various acreages of cereal grains. Using the available data, I will attempt a *simulation* approach to the problem, using Monte Carlo techniques to assess the variables and to overcome some of the data limitations. In making the assess-

In this assessment, average, 7 in 10, and minimum harvest expectations were used. When assessed on this basis, some 20 percent of farms were found to have "real" excess capacity even with a minimum harvest expectation, and another 25 percent had inadequate capacity in an average harvest year.[2] These findings seem to suggest that farmers have considerable difficulty in assessing or obtaining the capacity of machinery they require, but alternatively it may indicate that the model used does not allow for the possible range of values of the relevant variables. Either way, these results show the need for further exploration of the decision variables, whether to assess previous decisions or to guide those in the future.

To permit a more realistic analysis, the model used must take into account the fact that the variables involved will have a distribution or range of values, since a calculation based on the mean, mode, minimum, or any other specific value may not adequately define the effects of these variables. The models used previously have been restricted to specific values because of the limitations of the budgetary approach used to resolve the problem. If we use the more flexible tool of simulation, however, we can handle variables as probability distributions. When we handle them so, the formal decision model is of the form

$$Rr = \frac{N}{W_i \cdot D_j \cdot H_k}, \tag{3}$$

where the rate of work (W_i), harvesting days available (D_j), and the usable working hours on those days (H_k), each has an array of possible values. Provided that the distributions of these values are known or can be estimated, the harvesting machine capacity required over a range of years can be estimated.

Harvest Variables

In practice, the limits on the capacity of a harvesting system are not set at any precise acreage; but, as combine-harvester capacity is more fully used, beyond a certain point the cost of the harvesting operation increases. This increase in cost may arise in the form of (*a*) crop losses through grain shedding from the unharvested crop, (*b*) losses caused by weather damage to the unharvested crop, and (*c*) losses due to higher costs in other enterprises which compete for labor at this time of the year. These costs can, however, be minimized by combining in less-than-perfect harvesting conditions and then drying the grain by artificial means. Although the cost of drying increases with the amount of moisture to be removed, it is a cost more easily estimated than any of the three listed above, so that drying costs become a

[2] The term *"real" excess capacity* is used to denote those situations where the acreage of crops harvested is not only less than the capacity of the combine used but also within the capability of the next smallest machine.

convenient means of evaluating the timeliness of harvest operations. The amount of drying required, however, is likely to vary considerably with different combine working rates and in different harvesting conditions.

Rates of work

To assess the distribution of combine rates of work, I obtained, from survey diaries kept by a sample of 55 farmers in southeast England, information relating to different types of combine and the rates of work they achieved.[3] The data were recorded from different fields over three consecutive years. The combines held on the farms were classified into three size categories according to their physical characteristics and purchase price. The characteristics of the distributions obtained, as shown in Figure 1, are approximately normal, but show a marked skewness toward the higher rates of work, which seems to be greater for large machines.

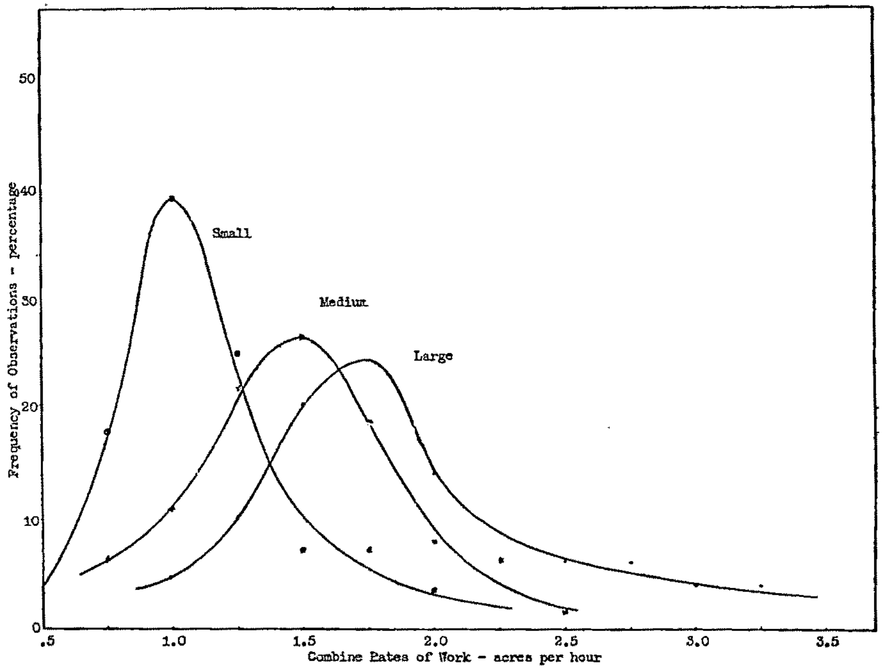

Figure 1. Distributions of combine rates of work

Since the data were recorded on different farms, in different fields, with different cereal crops, and over three separate years, the distributions could obviously conceal a number of variables. Using regression analysis,

[3] The data were recorded during the 1962–1964 cereal survey conducted in Kent and East Sussex by Wye College. The sample was selected at random and covered 66 combines on 55 farms; rates of work were measured on 132 fields.

I found no significant relationship between the rates of work achieved and either field size, crop yields, or the recording year. Similarly, I found no observable pattern in the rates obtained from any one farm over the three years considered. Some supporting evidence for the considerable variability encountered is provided by the National Institute of Agricultural Engineering, which reports that a "standard combine," used over a range of years and crops, has provided a similar wide distribution of rates of work.

The rates of work recorded seem somewhat less exceptional when it is remembered that the rates achieved include the stopping time for machine adjustment and other purposes and are further affected by the skill of the operator and the conditions of the crop. In general, it seems at least possible that the distributions presented here and used in the study overestimate the variability likely to be encountered on any one farm. Detailed records of combine use over ten years on the Wye College farm, however, suggest that the rates achieved can be at least as variable as those in Figure 1 but that when these rates are averaged over the several fields harvested on a farm in any one year the distributions in Figure 1 may slightly overestimate those realized in practice.

Rain-free days

After we have an expected range of operating rates, the next step is to define the operating time available and the grain moisture content during that time. For this purpose, data were extracted from historical weather records covering the 40-year period from 1922 to 1961.[4] The possible harvesting period considered was Shaw Weeks 39 to 46 inclusive—which include a period of 56 days, from July 30 to September 23 each year. These dates define the limits of the harvesting period in southeast England in all but the most unusual years.

Because of the difficulty in identifying an overall relationship between relative humidity of the air and grain moisture content in the standing crop, it was necessary to seek a less complete measure. The first criterion used was that of rain-free days. This was selected because, even though the grain moisture content may not rise sufficiently on wet days to prevent harvesting, the presence of moisture on the straw quickly makes combining impracticable. Hence, rainfall is an effective restriction on the harvesting time available. It is assumed that the days when harvesting is possible for some periods before rain will be balanced by periods when combining is impracticable because of rain late on the previous day.

[4] Weather data were obtained from East Malling Meteorological Station, which is one of the three base stations for recording weather statistics in the South-East District and the nearest to the survey area. The data used were taken from summaries prepared by Trowel [14, pp. 108–112]. These summaries were based on Shaw Weeks, which are standard seven-day periods equidistant from the equinox in all years.

The number of rain-free days (where *rain-free* equals less than 0.01 inches) was found to vary between a minimum of 19 and a maximum of 47 out of the 56 possible days, with a mean of 33 days free of rain. Over the 40-year period considered, the distribution of years with these numbers of days was fairly even. Since no clear pattern emerged in the distribution of the number of rain-free days, data for a longer period might seem desirable. The period of 40 years considered, however, is sufficient to take account of any short-term cycles which may be anticipated and would therefore seem to provide a sufficient guide to the expected future pattern of rain-free days.

Grain moisture content

Within the occurring rain-free days, the time available for combining is further restricted by the presence of surface moisture on the straw, arising from dew, and by the moisture content of the grain. The grain in the standing crop passes through a diurnal cycle of moisture content in concert with the ambient humidity. In most years, the grain moisture content exceeds 25 percent of the wet weight of the grain by midnight but drops rapidly from about 0400 hours to reach a minimum on a dry day at about 1400 hours, after which it begins to rise again. It is assumed that combining is feasible up to a maximum of 25 percent grain moisture content but that above this level the threshing losses will become intolerable.

It is assumed that during a rain-free day combining is physically possible for a period of about 12 hours—from 1000 hours to 2200 hours—and that outside these times the surface moisture formed on the straw from dew makes combining impossible. Within the limits of the 12 hours and the 25 percent maximum moisture content, the cost of drying increases with the level of the grain moisture content.

I evaluated the distribution of grain moisture-content levels within these hours, using data recorded by the National Institute of Agricultural Engineering. The original data consisted of detailed hourly readings of grain and air moisture and temperature levels, recorded 24 hours a day over four consecutive harvests. By selecting periods with various proportions of rain-free days from the years recorded, I found it possible to build up a pattern of the grain moisture content which I assume to be representative of years in which similar proportions of rain-free days occur during the harvesting period. The patterns of grain moisture content thus obtained are shown in Figure 2, in the form of cumulative time at successive moisture levels—the form in which they are most useful in simulation procedure. Using these data, I was able to estimate the distribution of grain moisture content for any particular year by interpolating between the cumulative grain moisture-content curves presented. I then used these distributions in the harvest simulation.

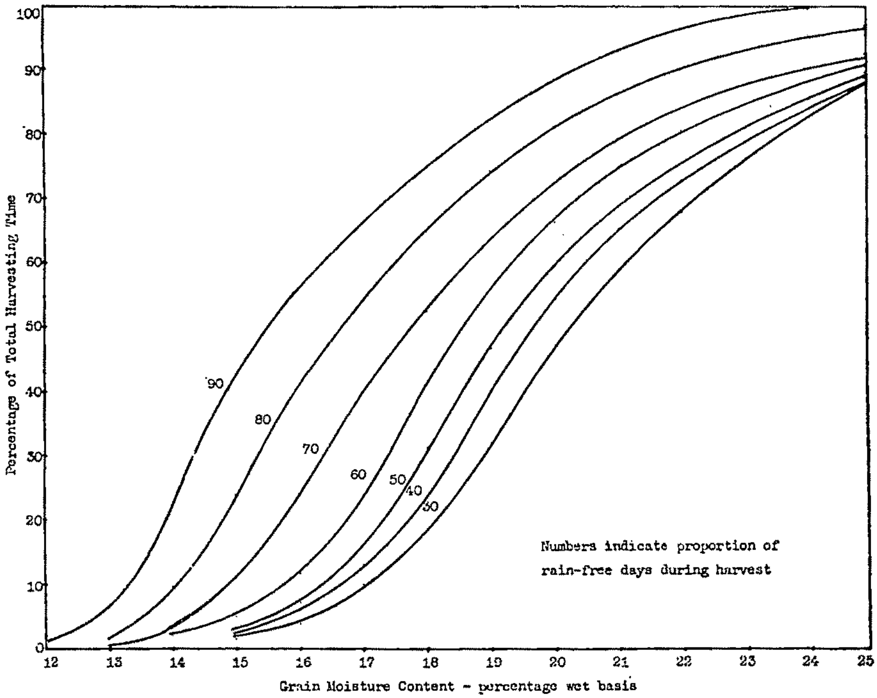

Figure 2. Cumulative grain moisture content during harvest

Harvest Simulation

A simulation, as the name implies, is fundamentally a means of working with selected aspects of reality. In a spectrum of management methods, ranging from analytical mathematical description on the one hand to experimentation with the actual system on the other, the term *simulation* might be applied to most of the methods in between.

This simulation is of the kind which uses symbolic schemes to represent a man–machine system, in which the relevant human behavior is either known or assumed to be known and is consequently reduced to data form. The method in this case uses those techniques sometimes known as "Monte Carlo methods." Basically, the procedure allows the evaluation of a probability distribution when only a sample from it is given. It does so by selecting values at random and then constraining them according to the dimensions suggested by the sample distribution. In practice, this was achieved for the large number of observations required, by the use of a computer routine which generated pseudo-random numbers.

As the simultation sequence was applied here, the first steps were to select a combine rate of work and then a harvest year with a particular number of rain-free harvest days, both of which were regarded as proba-

bilistic, with the known distributions previously outlined. The range of grain moisture content was then handled in two separate ways—first "deterministically" and then "probabilistically"—in order to simulate the outcomes from two alternative policies of the farmer, those of minimum drying and minimum harvesting time. The simulation was repeated for a range of harvesting systems of varying capacity, each comprising a combine plus a grain dryer, together with contract services for both operations wherever the capacity of machines owned was exceeded.

Minimum drying

In the first instance, it is assumed that the farmer makes full use of the best harvesting conditions available, regardless of the time lost in waiting for favorable weather. This involves assuming perfect knowledge of weather for the entire harvest. This is achieved in the simulation, once the year and number of rain-free days are selected, by regarding the pattern of grain moisture content related to those rain-free days as being determinate so far as the farmer is concerned. The supposition is that he first uses all of the hours when no drying is required and then uses progressively higher grain moisture-content levels until the crop is harvested. If he could do this, a farmer would incur the lowest possible drying cost for his cereal acreage in the particular year being considered. There are, however, two restrictions which limit this possibility.

First, since the dry days will be distributed unevenly throughout the eight weeks of the harvesting period, some considerable time will pass in waiting for the drier periods. During this waiting time, there may be considerable crop losses incurred through weather damage and grain shedding. There may also be lost labor hours, which may have a high opportunity cost at this time of year, so that the real harvesting cost may be higher than the cost of combining and drying estimated in this way.

Second, and quite apart from this, the proposition is impossible (unless there is a very small acreage to harvest) since the exact periods of time at the lowest grain moisture content are not known until the harvest is over. Consequently, a farmer will usually do some drying even though favorable drier periods of weather occur after he has done so. Nevertheless, he will probably make some use of the drier periods in at least some seasons, since in the earlier part of harvest he will defer combining high-moisture-content grain in anticipation of a more favorable time.

Minimum time

In the second simulation, it is assumed that the farmer makes full use of harvesting time whenever combining is possible, without regard to the drying costs incurred and without considering the expected weather pattern during the rest of the harvesting period. This is simulated by taking

an appropriate number of observations, say 25, from the pattern of grain moisture content for the year selected—thus regarding it as a probability distribution of grain moisture content confronting the farmer—and taking the average of these to represent the mean grain moisture content encountered during harvesting.

This assumption, like the minimum-drying assumption, is extreme in that it is highly likely that the farmer will not combine early in the season if working conditions are very poor and that he will proceed seven days a week if conditions are very favorable. The costs estimated on the basis of this assumption might therefore be regarded as the maximum costs likely to be incurred in practice. It might be expected that by incurring these higher drying costs, a farmer could keep costs from grain losses and lost working time to a minimum, given the capacity limits of different-sized harvesting systems.

Unit costs

Applying these basic assumptions, together with the data presented previously, I calculated the *average total cost per acre* for combining and drying successively higher acreages of cereals. This calculation was made according to the formula

$$(4) \qquad Ca = \frac{Fc + (Vc \cdot N) + Fd + (Vd \cdot Nd) + (Hd \cdot Nd\{M - 15\})}{N}$$

where

Fc is the fixed cost of combining,
Fd is the fixed cost of drying,
Vc is the variable cost of combining,
Vd is the variable cost of drying (less drying fuel),
Hd is the cost of fuel for drying, per 1 percent of moisture removed,
M is the moisture level of the grain,
N is the number of acres harvested, and
Nd is the number of acres dried.

In those years in which additional contract services were required to supplement the existing combine capacity, a different formula was used:

$$(5) \quad Ca = \frac{Fc + (Vc \cdot K) + (Cc\{N - K\}) + Fd + (Vd \cdot Nd) + (Hd \cdot Nd\{M - 15\})}{N},$$

where

K is the total physical capacity of the combine in that year, and
Cc is the per-acre cost of contract combining.

The fixed costs used in these calculations include depreciation, interest, insurance, vehicle tax, and a charge for shelter, calculated on current new prices and averaged over the first five years of machine life. The variable

costs comprise fuel and lubrication, repairs and maintenance, and operator's labor charges, estimated on a per-acre basis for both combine and dryer. The cost of fuel for grain drying was assessed separately in order to allow for the range of grain moisture content encountered in each year. It is assumed that no drying is required until the grain moisture level reaches 17 percent of the wet weight of the grain, and that once drying is necessary the normal procedure is to reduce it to 15 percent moisture content, at which it might be safely stored. The costs were based on average grain yields for the area of 29 cwt. per acre.

Based on these estimates and assumptions, the average total costs per acre were assessed for each system, over a range of acres, using 1,000 iterations. The results obtained are presented graphically in Figure 3. Apart from those for the three different-sized single combine systems, costs are also presented for some systems based on multiple combines.

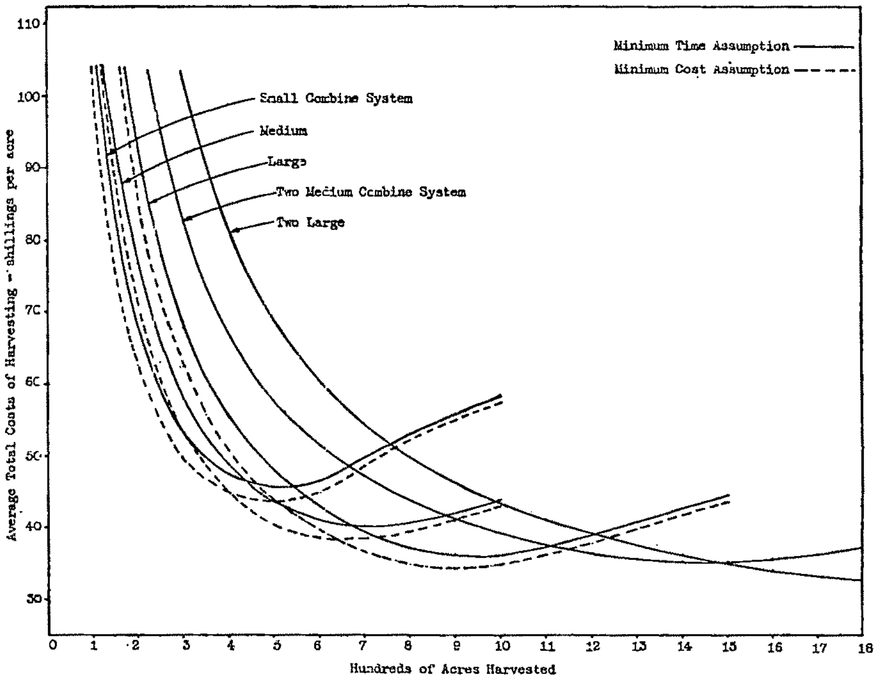

Figure 3. Unit costs of harvesting cereals—eight-week harvest

Physical limits

The results shown in Figure 3 represent the average costs per acre for different harvesting systems when the effects of the main quantifiable physical weather variables have been taken into account. In classic fashion, the *average total costs* decline as the fixed costs are spread over a greater

acreage, and then rise again as variable costs increase with increased acreage. Collectively the "family" of curves defines the long-run "planning curve" which confronts the cereal grower.

The difference in costs incurred under the "minimum drying" and "minimum time" assumptions is shown by the two curves presented for each of the three single combine systems. The difference in unit cost between the two represents the cost of removing the risk of not completing harvest through waiting for good harvesting weather. It will be noted, too, that the changeover points (indicated by the intersection of the average total cost curves for successively higher capacity systems) are at higher acreages for the higher cost or "minimum time" curves. This fact supports the notion that making fuller use of available drying facilities allows the capacity of the respective-sized combines to be effectively extended, albeit at some extra cost.

Although this assessment has taken into account all of the direct weather effects on the harvest operation, the capacity ranges for the various systems (as indicated by the points of intersection of the curves) are considerably higher than might be expected. In fact, when assessed on the capacity ranges indicated, all of the 55 farms in the farm survey previously mentioned would have *real excess* capacity in their harvesting systems—that is, they could complete their harvests more economically with a smaller capacity system. This fact suggests that there remain some limiting variables which need to be taken into account.

Biological tolerances

Predominant among the indirect weather effects on harvest operations are the husbandry dating or biological tolerances [4, p. 337]. In cereal harvesting, these effectively restrict the time period over which the various crop species and varieties reach maturity and ripeness, and the time for which they can stand after that date without incurring excessive grain losses.

The economic effects of these biological tolerances might be best taken into account by estimating a revenue curve for various combinations of cereal crops and varieties over a range of acres [10, p. 10]. The effects would thus be emphasized by changes in revenue as grain yields or losses increased or decreased. The nature of these biological effects is such, however, that a revenue curve would be highly characteristic for any one farm—more so than the average total cost curve for the physical operations—since the date of reaching combine ripeness and the time period required for successive crops to reach that stage are both influenced by a number of controlled variables. These include the varieties grown, seedbed preparation, fertilizer applications, rate and date of sowing, and type of after treatments. The altitude, slope, soil type, and micro-climate of the location, and the general weather effects during the growing period, add to the range

of possible variations. Hence these effects can, at best, be quantified as a distribution of distributions and cannot easily be assessed for a general situation. It is possible, however, having identified the major variables involved, to assess their general effects and to consider the subjective adjustments which farmers might make to these.

Although numerous factors will influence the date at which a crop reaches maturity, the period between the first and last fields reaching harvest ripeness in any year seems to be about three weeks, regardless of the spread of sowing dates. By using special varieties and husbandry practices it is possible to extend the period to more than three weeks. Similarly, unless a combination of cereal types and varieties is grown, the time span can be less than three weeks. It seems reasonable to expect, however, that, using some basic husbandry measures, a spread of three weeks can be achieved, in southeast England, in most years.

The length of time for which a ripe crop can stand without large grain shedding losses is, similarly, influenced by a number of factors. Published evidence suggests that the amount of grain lost in this way varies considerably from one variety to another and, because of weather effects, from one year to another [6]. This empirical evidence and field experience both suggest that for most varieties the shedding losses increase significantly after the crop has been standing, harvest ripe, for about three weeks.

Together, these tolerance limits suggest that a farmer may wish to complete his cereal harvest in a maximum of six weeks, rather than the eight weeks considered previously. To assess the effects of this further restriction, the harvest simulation was repeated, with the operating time constrained to the first six weeks of the period previously used. The cost curves obtained for both the six- and the eight-week assumptions are compared in Figure 4.

The two curves presented in Figure 4 for each harvesting system are both obtained by using the higher cost or "minimum time" assumption, wherein the pattern of grain moisture content is considered to be probabilistic. The cost difference, indicated by the space between the two cost curves for any one system, represents the opportunity cost of the grain saved by completing the harvest operation in six weeks. As might be expected, the changeover points, at which one system becomes cheaper than the other, occur at somewhat lower acreages than those under the eight-weeks assumption.

Under the assumption of a six-week harvesting period, there was found to be a mean of 25 rain-free days in the harvest period. This number accords well with the intuitive assessment of some farmers, whose estimates of their harvesting capacity requirements are based on what is variously stated to be between 21 and 28 available days.

For various reasons, such as the need to complete other operations at this time, some farmers may wish to complete their cereal harvest in four

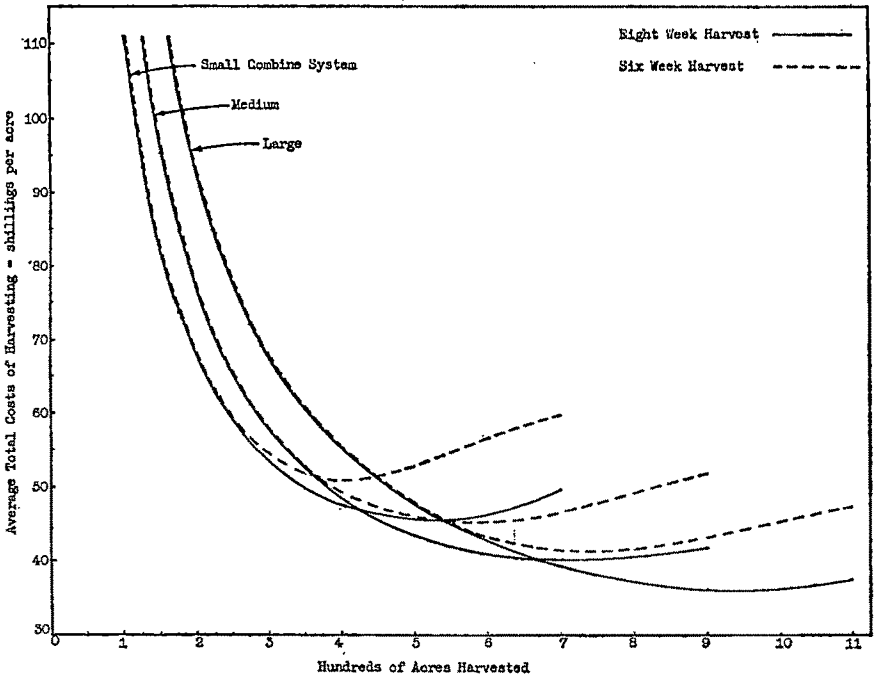

Figure 4. Unit costs of harvesting—six- and eight-week harvests

or five weeks rather than six or eight as considered here. The opportunity cost of using labor to complete the competing operations could readily be assessed by repeating the simulation with these additional constraints.[5] Used in this way, the harvest simulation can provide an abundance of information which could be used to guide farmers' decisions on the optimum system for their situations.

Decision Points

Decisions under risk

The aim of this study is to evaluate the effects on the capacity of harvesting systems arising from variables which might be quantified as probability distributions—that is, variables which constitute risk as opposed to uncertainty. The capacity of a mechanical harvesting system is determined, not only by the levels of these variables, but also, since they vary independently of one another, by the coincidence of their various levels. Thus, in order to assess the capacity of a system, it is necessary to consider the range of possible outcomes.

To do this, it is possible to select specific single values within the expecta-

[5] The effects of this constraint are presented and discussed in more detail, together with various other practical aspects and implications associated with this study, in a departmental bulletin [8].

tion range and to proceed with analysis on the basis of *assumed certainty*. This approach could be used to assess the impact of a variable by taking a series of such assumed certainty values [2, p. 174]. Where it is possible to refine the assessment, by substituting a known probability for the single value, the assessment is known as *certainty equivalence* of the decision under risk. Although this type of assessment is achieved in the harvest simulation, it is important to recognize that the results presented do not represent a definitive answer to the decision problem.

The results of this assessment, when presented as average total cost curves, constitute in fact an expectation model for the unit cost of harvesting cereals—based in this case on the mean of the range of possible cost outcomes. If the average cost curves could be regarded as certain, then the minimum cost system for harvesting any acreage could be selected by noting the lowest curve for that acreage, and the intersection of the curves would indicate the range of acres over which each system was the optimum. Alternatively, by altering the computing instructions, the marginal cost could be calculated and the intersection of the marginal cost curves could be used to indicate the capacity of ranges of the respective systems.

Because the variables are assessed by testing their effects over a simulated 1,000 "years," the cost calculated for each acreage is the mean of the costs estimated over this number of observations. The cost expectation for each acreage will, consequently, be a range of values, both higher and lower than the mean, probably having a normal distribution. In order to obtain some measure of the likely variance about the cost mean at each point, the *standard deviation* of the cost was calculated for each acreage level. The standard deviation gives a comparative measure of the risk involved at each acreage level.

For each harvesting system, the standard deviation is low for small acreages and increases as the capacity of the system is more fully extended. At higher acreages, the variation is as high as ten standard deviations, compared with between one and two for the downward-sloping region of the curve. If a high risk aversion is assumed on the part of farmers, the risk as measured by the standard deviation goes some way toward explaining the tendency for the capacity of harvesting systems maintained on farms to exceed the optimum ranges suggested by the average total cost curves. The capacity ranges delineated by the average total cost curve intersections, and those suggested by the point at which the cost variability exceeds two standard deviations, are shown in Table 1.

Empirical test

When assessed in relation to capacity ranges based on the standard deviation criterion for the six-week harvest simulation, the harvesting systems held on the survey farms seem better adjusted. Of the farms with "large" systems only 5 of 14 had "real" excess capacity; of those with "medium,"

Table 1. Capacity ranges for harvesting systems

Criteria	System	Minimum acres	Maximum acres
8 weeks A.T.C.	Small	(150)	430
	Medium	430	670
	Large	670	1100
8 weeks S.D.	Small	(150)	300
	Medium	300	470
	Large	470	770
6 weeks A.T.C.	Small	(150)	370
	Medium	370	550
	Large	550	900
6 weeks S.D.	Small	(150)	250
	Medium	250	330
	Large	320	560

10 of 21; and of those with "small" systems, 7 of 11. As is reasonable, none of the systems had inadequate capacity.[6]

The tendency toward more frequently occurring excess capacity among those with smaller systems may reflect the difficulty which they encounter in getting systems which are well adjusted to smaller acreages. There may, however, be other explanations. Approximately half of those farms with "real" excess capacity, based on the risk criteria, had second-hand combines. Since the fixed costs for these machines would thus be lower than those for a new combine, the actual cost curves would be nearer the origin, and the optimum capacity ranges consequently at somewhat lower acreages. There is the similar possibility that farmers may keep their equipment for longer than the five years assumed in estimating the costs used. If this is so, the fixed costs might again be slightly less and the capacity ranges accordingly slightly lower. There remains, however, a considerable amount of real excess capacity which is unexplained in this way.

In general, the evidence supports the notion that farmers have difficulty in assessing both the capacity of available equipment and their capacity requirements or, alternatively, that they encounter the limitations imposed by the "lumpiness" of machinery inputs when trying to obtain the capacity they require. If the former possibility is real, then the type of information yielded from the harvest simulation model may provide useful guidelines for machinery investment decisions.

Conclusion

Through use of the simulation model, it has been possible to assess the effects of both weather and operational variables on the expected capacity ranges of cereal harvesting equipment. In particular, the assessment has

[6] Although some farms were found to have inadequate capacity when based on budgeted standards, that assessment was for combines only, not for harvesting systems.

allowed some evaluation of the cost of timeliness in harvesting operations, through both extra grain drying and restricted time tolerances. Although there are many other variables which might be taken into account, the results obtained allow one to go some way toward making more accurate those decisions on harvesting machinery capacity which have to be made by farmers—usually on much less adequate information.

In this way, the study has demonstrated the usefulness of simulation models in yet another field of agriculture. At this stage, the usefulness of this particular model seems far from fully exploited. It is likely, for instance, that this or a similar model could be used to assess the scale effects of machine size, and that there is a real possibility of using the procedure to assess, ex ante, the place of new machines or the effect of innovations on existing machines. Work is at present proceeding along these lines.

References

[1] ARNOLD, R. E., "Cereal Moisture Contents in the Field," *Farm Mech.* 269–271, July 1955.

[2] DONALDSON, G. F., AND J. P. MCINERNEY, "Combine Capacity and Harvest Uncertainty," *Farm Econ.* 11 (4): 172–183, 1966.

[3] DONALDSON, G. F., "Optimum Harvesting Systems for Cereals: An Assessment for South-east England," Economics Department, Wye College, 1967.

[4] DUCKMAN, A. N., *Agricultural Synthesis: The Farming Year*, London, Chatto & Windus, 1963.

[5] ———, *The Role of Agricultural Meterology in Capital Investment Decisions*, Dept. of Agr. Rep. 2., University of Reading, Dec. 1966.

[6] FAJERSSON, F., AND M. KRANTZ, "Studies on Resistance to Shattering in Varieties of Winter and Spring Wheat at Weibullsholm, 1952–1965," *Agric. hort. genet.* 23: 101–171, 1965.

[7] HALTER, A. N., AND G. W. DEAN, "Use of Simulation in Evaluating Management Policies Under Uncertainty: Application to a Large Scale Ranch," *J. Farm Econ.* 47: 557–573, Aug. 1965.

[8] MCFARQUHAR, A. M. M., "Rational Decision-Making and Risk in Farm Planning—An Application of Quadratic Programming," *J. Agr. Econ.* 14: 552–563, Dec. 1961.

[9] MCINERNEY, J. P., "Maximin Programming: An Approach to Farm Planning Under Uncertainty," *J. Agr. Econ.* 18: 279–289, May 1967.

[10] MCQUIGG, J. D., and J. P. DOLL, "Weather Variability and Economic Analysis," *Missouri Agr. Exp. Sta. Res. Bul. 771*, June 1961.

[11] OURY, B., "Allowing for Weather in Crop Production Model Building," *J. Farm. Econ.* 47: 270–283, May 1965.

[12] SHAW, L. H., "The Effect of Weather on Agricultural Output: A Look at Methodology," *J. Farm. Econ.* 46: 218–230, Feb. 1964.

[13] THOMPSON, L. M., "Evaluation of Weather Factors in the Production of Grain Sorghums," *Agron. J.* 55: 182–185, 1963.

[14] TROWEL, G. F., "Forty Years of Weather at East Malling," *Annual Rep. East Malling Res. Sta., 1964.*

[15] ZUSMAN, PINHAUS, AND AMOTZ AMIAD, "Simulation: A Tool for Farm Planning Under Conditions of Weather Uncertainty," *J. Farm. Econ.* 47: 574–594, Aug. 1965.

Effects of Federal Income Taxes on Cattle-Ranch Prices*

WILLIAM E. MARTIN AND JIMMIE R. GATZ

Past studies have indicated that returns from beef production are not enough to justify economically the current prices of cattle ranches. It has been hypothesized that federal income taxes influence current ranch prices. Standard economic budgets are converted into tax budgets for use in testing this hypothesis. The procedure and assumptions involved in the analysis are briefly listed. Although tax savings can be substantial under specific assumptions, the general effect of ranches as tax shelters cannot be large enough to affect greatly the general level of ranch prices.

IN A recent article in this journal, Martin and Jefferies [8] showed that the level of current ranch sale prices is well above the level that would be reasonable if ranch purchasers had the single objective of raising beef for market. They advanced the hypothesis that the differential occurs because of the additional "outputs" accruing to the rancher which are not usually recognized by economists when computing reasonable ranch sale prices based on capitalized value. These additional outputs included "ranch fundamentalism," "conspicuous consumption," the possibility of land value appreciation, and the tax savings made possible by converting ordinary income into capital gains.

They concluded that "expectations of land appreciation may not loom large in investors' decisions to purchase leases" and that "since tax-shelter opportunities are not large relative to the differential to be explained, the major reason for high ranch prices must be the consumption-related outputs" [8, p. 239]. Support for the statements relative to land appreciation and the consumption-related activities were presented in detail in the article; the tax-shelter argument was not supported in detail but was based on preliminary research which has since been completed [5].

It is the purpose of this article to present in detail the effects of federal income taxes on current cattle ranch prices, to illustrate the method used in the analysis, and to list the detailed assumptions necessary for such an analysis to be made.

Previous Evidence of Tax Effects

What evidence exists that federal taxes may affect ranch prices? Of course, the basic opportunity for income taxes to increase ranch "output" and thus increase ranch value is provided by the possibility of converting

* Arizona Agr. Exp. Sta. J. Ser. Art. 1286.

WILLIAM E. MARTIN *is associate professor of agricultural economics and* JIMMIE R. GATZ *is a former research assistant in agricultural economics at the University of Arizona.*

ordinary income into capital gains. A general study by Butters *et al.* [2] confirmed that people with large incomes are greatly attracted by the differentially low tax rate on capital gains. In this journal, Beneke [1] emphasized the effects of taxes on farming efficiency through the effects of income variability, the allocation of costs and income between accounting periods, capital gains provisions, increases in leisure, and income in kind. Stocker [11] examined some effects of federal income taxes on the level and distribution of farm income. Wheeler [12] concluded that net tax benefits were of sufficient strength in many situations to attract resources from outside the agricultural economy into agriculture and to shift the use of resources within the farm to conform to certain tax advantages. Finally, the work of Dean and Carter [4], while mainly discussing the cost-increasing aspects of the income tax, briefly outlined some revenue-increasing possibilities, using orchards as an example. Work at Arizona with citrus orchard development [10] confirms that citrus orchards offer spectacular opportunities for the reduction of income tax. However, none of these studies have examined cattle ranches in particular.

The Necessity for Tax Analysis of Ranches

What is the size of the differential between current sale prices for cattle ranches and their capitalized values? From 1957 through 1963, a total of about 160 bona fide ranch sales occurred in Arizona BLM grazing districts 2 and 3, the BLM section 15 areas, the intermingled state lands, and the Tonto National Forest. The purchasers in 66 of these transfers were interviewed about variables affecting sale price. The average sale price for these ranches (including the deeded lands and the public grazing permits) was $932 per rated animal unit if the ranch was stocked and $599 per rated animal unit if no cattle were included in the sales [8]. Rough estimates of reasonable sale prices, given the single objective of raising beef for market, range around $200 to $250 per cow unit for unstocked ranches if computed from "representative" ranch budgets based on before-tax net income [7].[1]

Cost-and-return budgets of this type are a standard analytical tool of economists and others interested in representing the income position of individual "representative" firms within an industry. Such budgets usually assume an average year in a business of an unspecified length of life. The focus is on the inherent profitability of the business as an entity in itself. The implied goal is that the operator wishes to maximize profits to this business enterprise. Income taxes, if any, presumably are paid in graduated proportion to net returns on that business only.

[1] The most recently published summary of costs and returns for the western region [3] also provides data to support these estimates.

This simple model is adequate for firms where the owner of the business derives most his income from that one business source. The traditional owner-operated family farm is a good example. This model may not be adequate for cases where the business is simply one investment in an investor's portfolio. For this type of entrepreneur, the goal becomes maximum net returns after taxes over the course of time on all his business enterprises.

The latter situation appears to be generally applicable to new purchasers of Arizona ranches. Of the 66 new owners interviewed, 48 percent said that a tax shelter was one of their motives in the purchase. A different 48 percent earned more than 20 percent of their income from nonranch sources; 35 percent earned more than 80 percent of their income elsewhere. Seventy-three percent either claimed that they purchased the ranch for a tax shelter or earned more than 50 percent of their income from nonranch sources. These figures do not, in themselves, prove that the desire for income tax shelters is a real motive for ranch purchases or that such opportunities really exist. They do show, however, that ranch prices are being affected by purchases by men with more than the single interest in making money by producing beef. Therefore, we must go farther than the standard ranch budget if we are to examine the income-producing potential of a ranch operation. Many Arizona ranches are no longer the traditional owner-operated family firm.

Method of Analysis

Our approach in gauging the effects of income taxes on cattle ranch prices is quite simple in concept but extremely tedious and time-consuming in practice. It is simply to convert standard ranch budgets before taxes into ranch budgets after taxes and compare the capitalized values of the income streams before and after taxes.

The standard economic budgets are constructed to portray a "typical" year in the life of an existing operation. The implicit assumptions are that the ranch is a going operation being operated in a "normal" or "typical" fashion and is not being either bought or sold (or at least no tranfer costs or returns are realized). For tax budgets including an investigation of capital gains, it is necessary to assume a time of initiating and terminating the business and a specific method of making the ranch transfer, and to portray each year in the life of the business between time of purchase and time of sale.

Assumptions of Our Tax Model

The assumptions behind any economic model are crucial to the implications derived from it. The assumptions behind tax budgets are, by ne-

cessity, particularly complicated and only the barest outline can be given here. The details are available in Gatz [5].

1. *The Internal Revenue Tax Code* as of January 1965 is applicable. Thus, tax rates are lower than before the recent law changes of 1962 and 1964, and the rules are somewhat different. This assumption is in line with our objective, which is to observe the rationale of the decision to invest in ranches (or to hold previous investments in ranches) at existing levels of ranch incomes, expenses, and prices.

2. *Typical ranch investors* are married and file joint returns. Variations that exist in exemptions, deductions, and adjustments are avoided by assuming that the investors' nonranch incomes are large enough to offset them. Taxable income, as used in this study, is the amount of income subject to tax after exemptions, deductions, and adjustments have been subtracted from gross taxable income.

3. *Taxable profits* stemming from ranch ownership are taxed at the highest marginal tax rate applicable to the total income of the investor. Seventy percent is the highest tax bracket as of January 1965. Thus, the budgets of this study are constructed for investors with nonranch taxable incomes large enough to offset all ranch losses at the 70-percent rate. This requires annual nonranch taxable income of at least $225,000 for an investor in a "small" 200-animal-unit ranch and at least $250,000 for an investor in a "large" 700-animal-unit ranch. This assumption offers the largest possibility for a tax shelter. If returns are not increased enough in this extreme case to return to invested capital the going rate of interest, there is no point in examining the effects under lower tax rates.

4. *Ranches are owned* by individuals, partnerships, or Subchapter S corporations.[2] For these types of business organizations, losses will offset outside incomes. This is not true for corporations. Tax laws do not permit the offsetting of corporate loss against the personal incomes of stockholders. Thus, except for the carry-over loss provisions, no tax benefits may ever be realized. Examination of the standard ranch budgets indicates substantial tax losses in many cases. Therefore, the individual form of business organization was chosen so as to illustrate the maximum possibilities for tax savings.

5. *A choice of tax accounting procedures* is available [13]. We assume that the cash method of tax accounting is used, since this method may save taxes when capital gains are applied on the sale of raised breeding livestock. Under the cash method, the livestock have no cost basis, the cost of raising having been deducted as expenses against ordinary income. When raised breeding and draft animals are sold, the total sales price is taxable profit but is taxed at capital gains rates.

Additional 20-percent first-year depreciation is taken where applicable.

---

[2] As defined by the U. S. Treasury Department, Internal Revenue Service, 1965.

The declining-balance method is used for computing ordinary depreciation. Double the straight-line rates are used for assets purchased new, and one and one-half times the straight-line rates are used for assets purchased used. These fast-depreciation methods are used, in spite of the recapture rules, to enhance the time value of money.

6. *Down payments* of 25 percent are made upon purchase of a ranch, the balance to be paid in ten equal yearly installments, plus 6-percent interest on the unpaid balance.[3]

7. Our tax budgets are constructed to portray each year in *the life of the business* between the time of purchase and sale. This is necessary to check investment and operating decisions that relate to the time value of money. Alternative assumptions are that the life of the business is from 1 to 15 years in length.

8. *The breeding herd* is acquired with the ranch. Standard budgets implicitly assume fully stocked ranches. Our tax budgets are designed under the same assumption for comparison purposes; that is, the ranch is purchased fully stocked. Need for additional study relative to this assumption is indicated by the ranch purchases investigated by Jefferies [6]. Of the 66 ranch purchases, 30 included breeding herds and 36 were unstocked. The data and economic reasoning appear to be somewhat in conflict. It might seem that the greater taxable losses in the first years of building a breeding herd would be less costly to high-tax-rate investors and thus favor unstocked ranch purchases. However, the actual sales data showed that the price of a stocked ranch was very much higher than that of an unstocked ranch—that is, much higher than the value of the cattle would seem to warrant.

9. *The level of land prices* is held constant throughout the period of ownership in order to isolate the tax effects of owning a ranch from the speculative effects. Thus, the sale price of the ranch is the same as the purchase price, plus or minus adjustments for investment in and/or depreciation of improvements, machinery and equipment, and cattle.

This assumption is necessary for analytical purposes. However, although grazing land prices in Arizona have risen greatly in recent years, a statistical analysis of ranch sale prices for the years 1957 through 1963 showed no significant trend. Graphic analysis in terms of sale value per cow unit suggests that prices continued to rise until 1959 and have remained stable since. If expectations of rising land and lease values have been a factor in contributing to high purchase prices, these expectations have not lately been realized [9]. Further, as previously mentioned, Martin and Jefferies [8] showed that expectations of land appreciation may not be a large factor in the investor's decision to buy.

[3] Arizona real estate agencies dealing in ranch properties were personally interviewed in the summer of 1965. The characteristics of the typical ranch transfer were derived from these interviews.

The General Tax Budgeting Procedure

The total ranch price (including land, leases, cattle, buildings and improvements, and machinery and equipment) is allocated among the various classes of assets in order to compute taxable gain, transaction costs, and interest payments on sale of the ranch. Sale prices take both the depreciation of the original purchases and the value of replacement assets into account. Sale prices are computed for each asset class for each year of the life of the ranch up to a maximum life of 15 years.[4]

It is assumed that an operating, normally maintained ranch is purchased.[5] Purchased cows are depreciable, whereas, since we are using cash-basis tax accounting, raised cows are not. Capital gains taxes are computed on the difference between the depreciable balance and the sale price of purchased cows and on the total sale price of raised cows.

Depreciation is computed on each asset class by using the declining balance method and taking the additional 20-percent first-year depreciation where applicable. Two computations of depreciation are necessary, one on which actual sale prices are based and another to compute depreciation that is deductible from taxable income. The differences are taxable as gains on sale of the ranch.

Capital expenditures are made for new assets as old assets reach the end of their expected life. Net capital expenditures are equal to net cost minus salvage value. They are part of the costs included when one is computing present values according to tax budgets.

Investment credit is taken on wells, corrals, machinery, and equipment. Credit may not be taken on buildings, livestock, or land. It is assumed that no investment credit on nonranch property is taken by the owners, since such credit would limit the credit allowable on ranch property. Sale of the ranches necessitates the recomputation of investment credit taken on property for which the sale reduces the useful life to the extent that less credit is allowable than initially computed.

Costs, returns, taxes, and tax savings are computed in three separate operations relating to (1) income from yearly ranch operations, (2) gains upon sale of the ranch, and (3) costs and returns from buying and selling transactions.

---

[4] The basic data were obtained from a 1962 cost-and-returns study by Martin and Goss [7] and a 1964 land-value study by Jefferies [6].

[5] This is a crucial assumption but one which we think it perfectly legitimate to make. An alternative assumption would be that ranches were purchased when in rundown condition and that many special improvements were made. Our interviews relative to 66 ranch sales [6] did not support the alternative assumption; neither did our interviews with ranch operators when we were constructing the basic "typical" ranch budgets [7].

Ranch Values After Taxes

The foregoing discussion has briefly listed the computations necessary in constructing tax budgets. In the following sections, results of these computations are combined so as to estimate total ranch values. Comparison of computed ranch values, before and after taxes, will indicate the value of ranches as tax shelters under alternative conditions. All ranch values are expressed as the *present values* resulting from an expected future stream of costs and returns. A 5-percent discount rate is used throughout.

Standard before-tax budgets

The present values of the two representative ranches are obtained from standard before-tax budgets by treating returns to capital and management[6] as perpetuities. Returns are from yearly operations only. That is, no costs or returns from buying or selling the ranch enter into the computation.

The values are presented in Table 1. It is estimated that a 200-AU ranch returns a negative $1,538 per year to capital and management after all other inputs (including a hired manager) have been paid. The capitalized value of this return is a negative $30,760, which makes the difference between the market value of the ranch ($193,290) and the capitalized value of the ranch (–$30,760) equal $224,050.

Table 1. Ranch values from standard before-tax budgets

	Ranch size	
	200 AU	700 AU
	.... *dollars*	
Flow of net returns to capital and management per year	– 1,538	9,732
Present value of returns to capital and management[a]	–30,760	194,640
Market price	193,290	638,872
Difference between capitalized value and market price	224,050	444,232

[a] Discount rate used is 5 percent.
Source: Adapted from Martin and Goss [7], Caton [3], and Jefferies [6].

The 700-AU ranch, which takes advantage of economies of size [7], returns a positive income to capital and management of $9,732. Thus, the capitalized value of the ranch is also positive ($194,640). However, a

[6] *Management* is here defined as overall decision and risk-bearing functions of the owner, since a hired manager, who makes the day-to-day decisions, is included as a cost.

$444,232 difference remains between the capitalized value and the market price, which is $638,872.

Now let us examine the effects of federal income taxes and the buying and selling transactions upon these estimated capital values.

Operating returns, after taxes, to currently owned ranches

First, we retain the assumption of no buying or selling costs or returns. Thus, costs and returns are still from current operations only. Since there are no buying costs, the ranch is referred to as "currently owned."

Taxes and tax savings on yearly operations come from two sources, investment credit and ranch operating profits and losses. Investment credit is dependent on capital expenditures.

In order to budget capital expenditures properly, one really needs to assume a year of purchase and an original ranch inventory. This is done in later tax budgets where the buying operation is included. However, for these currently owned, after-tax budgets, where no such base points are available, an average-per-year capital expenditure was computed from the standard before-tax budgets. In the more precise tax budgets, investment credit averages 5 percent of net capital expenditures. Thus, present values of average investment credit are computed as 5 percent of present values of average net capital expenditures, as shown in Table 2.

Table 2. Present values of costs and returns before and after taxes from operating currently owned ranches

Present values	Ranch size	
	200 AU	700 AU
	dollars	
Costs and returns before taxes		
Net cash incomes for tax purposes	6,560	272,520
Net capital expenditures for tax purposes	37,320	77,880
Net returns before taxes	−30,760	194,640
Taxes and tax savings		
Investment credit	1,886	3,894
Tax savings from operations	37,120	
Taxes paid on operations		69,400
Net tax savings	38,986	
Net taxes paid		65,506
Net returns after taxes	8,226	129,134
Market prices	193,290	638,872

Table 2 is interpreted as follows. Because annual net returns to capital and management for the 200-AU ranch are negative (Table 1), the present value of these net returns before taxes is −$30,760 (Tables 1 and 2). However, net *cash* income for *tax purposes* is positive. The present value of this net cash income flow is $6,560. The difference between net cash

income for tax purposes and net returns before taxes is equal to net capital expenditures (depreciation) for tax purposes, or $37,320.

Since net taxable income (as distinguished from net cash income) is negative (cash income less depreciation), there are tax savings of $37,120 on the owner's nonranch income. These tax savings result from the day-to-day operations of the ranch. In addition, there are savings of $1,866 from investment credit. The present value of the sum of these two sources of savings is $38,986. The present value of net returns from the ranch before taxes is −$30,760. Because of net tax savings of $38,986 the present value of net returns from the ranch after taxes is $8,226. The tax laws have increased the value of the ranch by $38,986, but $8,226 is still far below the market price of $193,290.

For the 700-AU ranch, net returns before taxes are positive ($194,640). Since returns before taxes are positive, the only tax savings are from investment credit. Net taxes of $65,506 are paid. The after-tax value of the ranch is reduced from $194,640 to $129,134; the gap between the computed value of the ranch and the market price is widened.

These values are converted to annual rates of return to capital and management and are shown in Table 3.

Table 3. Annual rates of return to capital and management before and after taxes from operating currently owned ranches

	Ranch size			
	200 AU		700 AU	
	Annual rate		Annual rate	
	dollars	*percent of investment*	*dollars*	*percent of investment*
Standard before-tax budgets	−1,538	−0.80	9,732	1.52
After-tax budget	411	0.21	6,457	1.01

Operating returns, after taxes, to a recently purchased ranch

Tax liabilities in the years immediately following the purchase of a ranch differ from those incurred in later years of a ranch's life. Recently purchased ranches may experience an erratic pattern of capital expenditures, depreciate purchased cows which are gradually replaced by nondepreciable raised cows, and use rapid depreciation methods for most assets. For budgets to reflect these abnormal tax effects, it is necessary to assume a specific pattern of depreciation and asset replacement. Because of these special effects, operating returns after taxes are larger for a re-

cently purchased ranch than for a ranch that has been owned for eight or more years.

Present values of costs and returns from operations before taxes are shown in Table 4. Each row shows the present value of the flows of costs and returns as of a particular number of years of operation after purchase of the ranch.

Table 4. Present values of flows of costs and returns, before taxes, from operating for various numbers of years after purchase of a ranch

Years of operation	Ranch size							
	200 AU				700 AU			
	Net cash income	Net capital expenditures	Difference in market values[a]	Total returns before taxes	Net cash income	Net capital expenditures	Difference in market values[a]	Total returns before taxes
	dollars							
1	328	173	4,353	− 4,198	13,626	4,336	8,803	487
2	610	3,671	2,497	− 5,558	25,336	5,023	11,070	9,243
3	893	5,311	2,263	− 6,681	37,106	10,439	9,190	17,477
4	1,163	5,585	3,218	− 7,640	48,318	14,094	8,907	25,317
5	1,420	5,727	3,957	− 8,264	58,994	17,543	8,588	32,863
6	1,665	5,863	4,652	− 8,860	69,161	18,108	10,390	40,663
7	1,898	11,258	3,256	−12,626	78,845	21,344	9,961	47,540
8	2,210	12,543	1,835	−12,258	88,068	28,895	5,712	53,461
9	2,331	12,693	1,652	−12,024	96,851	32,936	4,517	59,389
10	2,533	12,805	2,292	−12,564	105,216	36,314	3,901	65,001
11	2,724	12,911	2,931	−13,168	113,183	38,799	3,790	70,594
12	2,907	15,143	1,757	−13,993	120,771	41,104	3,731	75,936
13	3,081	15,400	2,396	−14,715	127,997	43,518	3,619	80,860
14	3,247	15,492	2,838	−15,133	134,878	43,900	4,961	86,017
15	3,405	16,725	2,157	−15,477	141,434	47,455	3,545	90,434

[a] All differences are *decreases* in market value.

As previously explained, net cash incomes for tax purposes are less than actual net cash incomes. Also, net capital expenditures are less than actual depreciation. This is because capital expenditures on wells, fences, livestock equipment, shop equipment, and tools are treated as cash costs for tax purposes.

Net capital expenditures vary considerably from year to year and do not exactly equal the relatively stable depreciation that occurs. Therefore, a difference exists in the price paid for a ranch when it is purchased and the price received for a ranch when it is sold, even though a stable general price level is assumed. This difference is attributed to the yearly operations of the ranch. Differences in the present values of these two market prices (rather than differences in the actual market prices) are shown in Table 4.

Table 4 is interpreted in the following manner. The present value of the flow of costs and returns, before taxes, from operating the 200-AU ranch for four years is –$7,640. This was obtained by subtracting the present value of the flow of net capital expenditures ($5,585) and the difference (decrease) in market value ($3,218) from the present value of the flow of net cash income ($1,163).

Taxes and tax savings from yearly operation come from taxable profits or losses and investment credit. Present values of these items are shown in Table 5 for up to 15 years of operation after purchase of a ranch. Present values of taxes saved on operations of the smaller ranch continue to increase through all years budgeted. However, present values of taxes saved on operations of the larger ranch increase only through the fifth year; operations on this ranch yield taxable incomes on which taxes must be paid after the fifth year. Investment credit continues to increase in both cases because total capital expenditures increase with time, but the increase in credit is not enough to offset the increase in taxes due to operations on the larger ranch.

Table 5. Present values of flows of taxes saved on operating for various numbers of years after purchase of a ranch

Years of operation	Ranch size: 200 AU			Ranch size: 700 AU		
	Taxes saved on operations	Investment credit	Total taxes saved	Taxes saved on operations	Investment credit	Total taxes saved
	dollars					
1	7,384	1,161	8,545	12,126	3,368	15,494
2	10,504	1,161	11,665	13,870	3,602	17,472
3	13,444	1,386	14,830	14,569	3,612	18,181
4	16,411	1,468	17,879	14,867	3,942	18,809
5	18,868	1,477	20,345	14,908	4,138	19,046
6	20,889	1,477	22,366	14,382	4,339	18,721
7	22,796	1,477	24,273	13,725	4,347	18,072
8	23,884	1,883	25,767	10,415	4,522	14,937
9	25,422	1,947	27,369	8,917	5,187	14,104
10	26,930	1,950	28,880	7,144	5,433	12,577
11	28,009	1,950	29,959	4,985	5,510	10,495
12	29,054	1,950	31,004	2,347	5,654	8,001
13	30,308	2,094	32,402	1,894	5,787	7,681
14	30,993	2,094	33,087	–659	5,917	5,258
15	31,645	2,094	33,739	–2,924	5,923	2,999

Returns before taxes (Table 4) and taxes saved (Table 5) are totaled and presented in Table 6. For example, for the 200-AU ranch for four years of operation after its purchase, –$7,640 total returns before taxes plus $17,879 in taxes saved equals a net present value of $10,239.

Table 6. Present values of flows of returns after taxes, from operating for various numbers of years after purchase of a ranch

Years of operation	Ranch size	
	200 AU	700 AU
	dollars	
1	4,347	15,981
2	6,107	26,715
3	8,149	35,658
4	10,239	44,126
5	12,081	51,909
6	13,506	59,384
7	11,647	65,612
8	13,509	68,398
9	15,345	73,502
10	16,316	77,578
11	16,791	81,089
12	17,011	83,937
13	17,687	88,541
14	17,954	91,275
15	18,262	93,433

Taxes saved in the years of operation immediately following purchase of the ranch exceeded taxes saved in later years. The difference can be illustrated in the following manner (Table 7).

Table 7. Net advantage of ranches purchased at the present over currently owned ranches

Present values	Ranch size	
	200 AU	700 AU
	dollars	
Normal returns after taxes	8,226	129,134
Discounted 15 years	3,957	62,113
15 years' returns from recently purchased ranches	20,419	96,978
Returns of recently purchased ranches not to be sold	24,376	159,091
Differences in operating returns from currently owned and recently purchased ranches	16,150	29,957
Costs of buying	12,726	42,027
Net advantage of recently purchased ranches over currently owned ranches	3,424	−12,070

It can reasonably be assumed that returns will be normal (stabilized) after 15 years. The flow of normal returns, as described in Table 2, is assumed to begin in the sixteenth year (Step 1). (This is the same as infinite additional years of operation.) The present values of the normal returns (Table 2) are, therefore, discounted an additional 15 years (Step 2). These present values (Step 2) are added to the present values of operating for the first 15 years (Step 3). Then the differences in present

values of returns to operations by current owners (Step 1) and by new owners (Step 4) are found. These differences (Step 5) can be attributed to the abnormal tax effects on operations occurring in the first 15 years, with the effect greatest the first year and diminishing with each passing year. Thus, the recently purchased 200-AU ranch has a $16,150 advantage over one that has been owned for more than 15 years, and the recently purchased 700-AU ranch has a $29,957 advantage. However, this advantage is for operating returns only. When the costs of buying the new ranch are added in Step 6, the differences in present values of operating returns between currently owned and recently purchased ranches (Step 5) are mostly offset for the smaller ranch and more than offset for the larger ranch. The net advantage is only $3,424 for the smaller ranch and −$12,070 for the larger operation.

Selling recently purchased ranches

We now complete the picture by adding in the costs and returns occurring when a ranch is sold within 15 years after its purchase. These effects are added to the values due to purchasing and operating, to obtain the total estimated present value of a ranch at the time just before purchase, assuming that the investor's goal is to sell the ranch after a given number of years. A continuing assumption is that no real estate appreciation occurs.

Selling costs and returns vary from year to year. The value of a ranch varies because the amount of net capital expenditures made from year to year does not exactly equal the amount of actual depreciation. These differences in value were attributed to the yearly operation costs of the ranch as shown in Table 4. Since land values are held constant, no real gains other than interest received on installment payments due are realized from the sale.

Tax effects, in addition to those resulting from interest received and transfer costs, are caused by gain on assets sold merely because of tax accounting, and by recaptured investment credit. The present value of taxes in the year of sale was computed by discounting the actual tax values for the 200-AU ranches. Components of this tax are tax savings on transaction costs, and taxes on ordinary gain, capital gain, and recaptured investment credit. Taxes on interest are the present values of taxes to be paid on interest to be received over the ten-year period. Taxes on interest vary from the 70-percent tax rate only because of the discounting procedures.

Net returns, before taxes, from selling are added to total taxes paid because of selling, to obtain the present value of after-tax returns occurring because of a ranch sale. The net value of a sale is almost always negative. The value becomes more negative for the first few years of operation, thereafter fluctuating slightly as the value of the ranch fluctuates.

The Net Results

Present values of buying costs, operating returns, and selling costs are combined to obtain the net present value from the point of view of an investor considering the purchase of a ranch which would be sold after a given number of years of operation. Results, after taxes, are as presented in Table 8.

Table 8. Total present values, after taxes, from buying, operating, and selling a ranch

Year	Ranch size							
	200 AU				700 AU			
	Buying costs	Operating returns	Selling costs	Total	Buying costs	Operating returns	Selling costs	Total
	dollars							
1	−12,726	4,347	3,293	−5,086	−42,027	15,981	− 454	−26,500
2	−12,726	6,107	2,148	−4,471	−42,027	26,715	− 2,128	−17,440
3	−12,726	8,149	962	−3,615	−42,027	35,658	− 5,684	−12,053
4	−12,726	10,239	136	−2,451	−42,027	44,126	− 7,496	− 5,397
5	−12,726	12,081	− 811	−1,456	−42,027	51,909	− 9,913	− 31
6	−12,726	13,506	− 863	− 83	−42,027	59,384	−10,484	6,873
7	−12,726	11,647	−1,088	−2,167	−42,027	65,612	−11,226	12,359
8	−12,726	13,509	−1,558	− 775	−42,027	68,398	− 9,801	16,570
9	−12,726	15,345	−1,596	1,023	−42,027	73,502	−11,178	20,297
10	−12,726	16,316	−2,051	1,539	−42,027	77,578	−11,827	23,724
11	−12,726	16,791	−2,043	2,022	−42,027	81,089	−11,727	27,335
12	−12,726	17,011	−2,049	2,236	−42,027	83,937	−11,155	30,755
13	−12,726	17,687	−2,449	2,512	−42,027	88,541	−12,593	33,921
14	−12,726	17,954	−2,274	2,954	−42,027	91,275	−11,978	32,270
15	−12,726	18,262	−1,931	3,605	−42,027	93,433	−11,195	40,211
∞	−12,726	22,219		9,493	−42,027	155,546		113,519

As long as the planning horizon is less than eight years for the smaller ranch and less than five years for the larger ranch, the total after-tax value of the ranch investment is negative. As the planning horizon expands, the present value of returns from operations increases (though at a decreasing rate), finally exceeding the costs of buying and selling. The longer the ranch is held, the larger is the total net value of after-tax returns. With a planning horizon of infinity, the values are $9,493 for the smaller ranch and $113,519 for the larger.

Conclusions

While cattle ranches may operate as tax shelters under particular and highly specific cases, the general effects of ranches as tax shelters should not presently be greatly affecting the general level of ranch prices. For any large tax-saving effects to occur, the value of the ranch must increase significantly between the time of purchase and the time of sale. This can happen in particular cases where a large number of improvements are put into the ranch (and mostly charged off as operating expense), but could not be typical of ranch sales.[7] Even where tax savings were shown to

[7] Thus, ranches present a very different case from the situation described by Gatz [5], where the *typical* investor in young citrus orchards can hardly help making tax savings, and the *general level* of citrus orchard prices is obviously affected.

occur, the value of these savings was small relative to the amount of ranch sale price to be explained.

Any advantage of the high-tax-bracket over the low-tax-bracket investor will result from investment in relatively small ranches, if the ranches are organized and run in a typical fashion. This study used a 200-AU ranch as an example of a small unit. Such a ranch has high fixed investment costs relative to total beef output. Although this ranch may have a negative taxable income, tax savings on depreciation, investment credit, and operating losses can make the after-tax value of the ranch positive. However, the balance among the various categories of costs and returns is crucial. Either a too-large operating loss or no operating loss destroys the tax shelter.

The tax advantage of smaller ranches may counteract the tendency toward large size due to economies of large-scale production. A 700-AU ranch loses its before-tax advantage because of technical efficiency if federal income taxes are considered.

References

[1] BENEKE, RAYMOND, "Some Effects of Income Tax Regulations on Farming Efficiency," *J. Farm Econ.* 34:520–534, Nov. 1952.

[2] BUTTERS, J. KEITH, LAWRENCE E. THOMPSON, AND LYNN L. BOLLINGER, *Effects of Taxation: Investments by Individuals,* Boston, Graduate School of Business Administration, Harvard University, 1953.

[3] CATON, D. D. (Project Leader), *Effects of Changes in Grazing Fees and Permitted Use of Public Rangelands on Incomes of Western Livestock Ranches,* USDA ERS 248, 1965.

[4] DEAN, GERALD W., AND H. O. CARTER, "Some Effects of Income Taxes on Large-Scale Agriculture," *J. Farm Econ.* 44:754–768, Aug. 1962.

[5] GATZ, JIMMIE R., "The Effects of Federal Income Taxes on Arizona Cattle Ranch Investments," unpublished M.S. thesis, University of Arizona, 1966.

[6] JEFFERIES, GENE L., "The Marginal Value of Public Grazing Permits to Arizona Ranchers," unpublished M.S. thesis, University of Arizona, 1964.

[7] MARTIN, WILLIAM E., AND WILLIAM K. GOSS, *Cost–Size Relationships for Southwestern Arizona Cattle Ranches,* Arizona Agr. Exp. Sta. Tech. Bul. 155, Nov. 1963.

[8] MARTIN, WILLIAM E., AND GENE L. JEFFERIES, "Relating Ranch Prices and Grazing Permit Values to Ranch Productivity," *J. Farm Econ.* 48:233–242, May 1966.

[9] ——, "Arizona Cattle Ranch Prices Remain Constant," *Progressive Agr. in Arizona* 17(4):12–13, July–Aug. 1965.

[10] SPEARS, ROBERT L., "Federal Income Taxes and the Structure of the Arizona Citrus Industry," unpublished M.S. thesis, University of Arizona, 1966.

[11] STOCKER, FREDERICK D., "The Impact of Federal Income Taxes on Farm People," USDA ARS 43–11, July 1955.

[12] WHEELER, RICHARD O., "The Possible Effects of the Federal Income Tax on Resource Use," *Proceedings of the Western Farm Econ. Assoc.* 32:147–150, 1959.

[13] U. S. Treasury Department, Internal Revenue Service, *Tax Code and Regulations,* Washington, Government Printing Office, 1965.

Combining Cross-Section and Time-Series Information on Demand Relationships for Substitute Goods

R. A. Holmes*

This study deals with the problem of pooling cross-section and time-series results in the estimation of demand functions when the appropriate endogenous variable differs in the two analyses. An iterative estimation procedure which incorporates a necessary distinction between quantity and quality elasticities of demand is developed and tested. This procedure addresses the estimation problems arising from differences between the cross-section and time-series models and data, and provides a partial test of the model specification.

ESTIMATES of demand functions from time series generally include, as exogenous variables, both income and time, which are closely correlated series, and the resulting estimation problems are frequently handled by obtaining an extraneous estimate of the income coefficient from cross-section data. However, the techniques which are generally employed take the price variable as exogenous in both the cross-section and time-series analyses [6], and this procedure may be invalid in some circumstances. The purpose of this article is to develop a method for estimating demand functions for substitute products by pooling cross-section data, in which the price of the commodity is appropriately taken as exogenous and quantity as endogenous, with time-series data, in which the reverse is true.

In the economic theory of demand, the point of view traditionally taken is that of the individual consumer, so that it is customary to think of quantities purchased adjusting to given prices. This is certainly the direction of causation from the individual consumer's viewpoint, since he, or she, individually, has little or no effect on prices and must generally adjust expenditures to the given array of prices. Consequently, with cross-section data which provide observations on individual consumers, prices of commodities should be taken as exogenous, and quantities as endogenous, variables.

The situation may differ with time-series data, however, since these typically provide observations aggregated over groups of consumers rather than observations of individual consumers. In the aggregate, quantities supplied may adjust to price only in periods longer than one year, so that the direction of causation in any given year may run the other way, that is, from quantities to prices of commodities [7].

* The assistance provided by the Agricultural Economics Research Council of Canada is gratefully acknowledged. In addition, valuable comments were received from Joseph Havlicek and an anonymous *Journal* reviewer.

R. A. Holmes *is associate professor of economics at Simon Fraser University, Burnaby, B. C., Canada.*

For example, the production of beef and pork is, in a given market, predetermined by the decisions which producers have made in previous years in response to past prices and price expectations. Increases in supply involve increased breeding programs followed by a gestation and feeding period which involves well over a year in the case of beef and about 10 or 11 months in the case of pork. Thus, the current prices of beef have no effect on production until later years, and with pork production, the supplies of at least 10 or 11 months of the current year are the result of decisions made in the years previous.

Therefore, it may be preferable, in the case of beef and pork, to reverse the usual procedure of taking prices as exogenous and quantities as endogenous variables (which is appropriate with cross-section data) when working with time series. When preferable, this change of procedure complicates the pooling of cross-section and time-series results, because it does not solve the basic multicollinearity problem, and it makes the transference of the income coefficient from the cross-section equation to the time-series equation more difficult.

The Model

The model employed is a just-identified system consisting of the following two structural equations:

$$(1) \qquad Q'_{1t} = a_1 + b_{11}P'_{1t} + b_{12}P'_{2t} + b_{13}YI_t + b_{14}T_t + u_{1t}$$

and

$$(2) \qquad Q'_{2t} = a_2 + b_{21}P'_{1t} + b_{22}P'_{2t} + b_{23}YI_t + b_{24}T_t + u_{2t},$$

where

Q'_{1t} and Q'_{2t} are logarithms of the quantities per adult equivalent consumed for two substitute products in time period t (see Prais and Houthakker for method of measuring adult equivalence [5]),

P'_{1t} and P'_{2t} are logarithms of the real prices of the two products in time period t,

YI_t are reciprocals of real disposable income per capita in time period t,

T_t is the time variable, and

u_{1t} and u_{2t} are disturbance terms.

The use of logarithms of prices and quantities implies constant price elasticities of demand, whereas the use of the reciprocal of the income variable implies that the income elasticity of demand is inversely proportional to the level of income and also provides for a saturation level of consumption as income increases. These constraints are particularly suited to demand functions for substitute food products, and other transformations of the variables might be needed for products other than foods.

If quantities rather than prices are the exogenous variables with aggre-

gate annual time-series data, the reduced form (see Meinken *et al.* [4] for derivation of similar results) of these two equations is given by

$$P'_{1t} = \alpha_1 + \beta_{11}Q'_{1t} + \beta_{12}Q'_{2t} + \beta_{13}YI_t + \beta_{14}T_t \tag{3}$$

and

$$P'_{2t} = \alpha_2 + \beta_{21}Q'_{1t} + \beta_{22}Q'_{2t} + \beta_{23}YI_t + \beta_{24}T_t, \tag{4}$$

where

$$b_{11} = \frac{\beta_{22}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}}, \qquad b_{22} = \frac{\beta_{11}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}},$$

$$b_{12} = \frac{-\beta_{12}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}}, \qquad b_{21} = \frac{-\beta_{21}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}},$$

$$b_{13} = \frac{\beta_{12}\beta_{23} - \beta_{13}\beta_{22}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}}, \qquad b_{23} = \frac{\beta_{21}\beta_{13} - \beta_{23}\beta_{11}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}},$$

$$b_{14} = \frac{\beta_{12}\beta_{24} - \beta_{14}\beta_{22}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}}, \qquad b_{24} = \frac{\beta_{21}\beta_{14} - \beta_{24}\beta_{11}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}}.$$

Our purpose is to estimate the coefficients b_{ij} in structural equations (1) and (2), but we must begin by estimating the coefficients β_{ij} in the reduced-form equations, (3) and (4). Our problem arises from the intercorrelation between the income and time variables, which makes it impossible to estimate β_{13}, β_{14}, β_{23}, and β_{24} reliably from time series. Consequently, we wish to employ budget data to estimate the partial effects of income.

The Problems

Two basic problems arise in attempting to pool cross-section and time-series results in this model. In the first place, the endogenous variable differs in the two regressions, so that one cannot directly substitute the income coefficients obtained from the cross-section data in the time-series equations. One can, of course, solve the cross-section regression equations for the price variables algebraically, but this is unsatisfactory because the algebraic solution ignores the influence of the disturbance terms and may not provide the correct statistical solution.

In addition, budget data generally provide information on expenditures rather than quantities purchased; for this reason, the resulting income coefficients are likely to be larger than those obtainable from, or applicable to, time-series data, because, as income increases, expenditures on most commodities reflect improved varieties and qualities bought, as well as increases in quantities purchased [3]. Consequently, one must take account of the upward bias in cross-section estimates of income elasticities.

The Solution

We begin by recognizing that the change in expenditure resulting from a change in income may [5] be expressed as

$$\frac{\partial V_{ij}}{\partial Y_j} = P_{ij}\frac{\partial Q_{ij}}{\partial Y_j} + Q_{ij}\frac{\partial P_{ij}}{\partial Y_j}, \tag{5}$$

where

V_{ij} is the expenditure on commodity i by household j,
Y_j is the income of household j,
P_{ij} is the price of commodity i bought by household j, and
Q_{ij} is the quantity of commodity i bought by household j.

The expenditure elasticity can therefore be obtained by multiplying both sides of equation (5) by Y_i/V_{ij}, to obtain

$$\frac{\partial V_{ij}}{\partial Y_j}\frac{Y_j}{V_{ij}} = \frac{\partial Q_{ij}}{\partial Y_j}\frac{Y_j}{Q_{ij}} + \frac{\partial P_{ij}}{\partial Y_j}\frac{Y_j}{P_{ij}}. \tag{6}$$

Equation (6) indicates that the quantity elasticity can be obtained by subtracting the quality elasticity (as measured by price) from the expenditure elasticity (all elasticities with respect to income) [5].

Suppose that the two resulting estimates of quantity elasticities are designated η_{1t} and η_{2t}. Then the coefficients b_{13} and b_{23} may be obtained from

$$\eta_{1t} = -b_{13}YI_t \tag{7}$$

and

$$\eta_{2t} = -b_{23}YI_t. \tag{8}$$

On the basis of these and previous time-series estimates of the coefficients β_{ij}, improved estimates of the coefficients β_{13} and β_{23} can be obtained from

$$b_{13} = \frac{\beta_{12}\beta_{23} - \beta_{13}\beta_{22}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}} \tag{9}$$

and

$$b_{23} = \frac{\beta_{21}\beta_{13} - \beta_{23}\beta_{11}}{\beta_{22}\beta_{11} - \beta_{12}\beta_{21}}. \tag{10}$$

These two equations in the two unknowns β_{13} and β_{23} can be solved and used subsequently to provide improved estimates of the other β_{ij} by defining two new variables,

$$PR'_{1t} = P'_{1t} - \beta_{13}YI_t \tag{11}$$

and

$$PR'_{2t} = P'_{2t} - \beta_{23} YI_t, \tag{12}$$

each of which is regressed on the variables Q'_{1t}, Q'_{2t}, and T_t to measure their partial relationships. In other words, the extraneous estimates of the income coefficients are used by eliminating their influence from P'_1 and P'_2 and estimating the remaining partial regression coefficients from the residuals. This is an iterative process, since each time the other β_{ij} are estimated, they provide improved estimates of β_{13} and β_{23}, which are in turn used to improve the estimates of the other β_{ij}.

In this iteration procedure, the income coefficients obtained for the structural equations from cross-section data (b_{13} and b_{23}), are left unchanged. The purpose of the iteration is to revise the reduced-form coefficients (β_{ij}) to be consistent with both the b_{13} and b_{23} coefficients and the time-series data. This consistency is, of course, desirable when cross-section and time-series results are pooled.

Moreover, and perhaps more important, the changes which occur under iteration provide a partial test of the model specification. If the specification were exact and perfect, the results obtained from the cross-section data would be immediately consistent with the time-series results, and none of the coefficients would change after the first round of the iteration procedure. The disturbance terms in the specification of cross-section equations may, of course, lead to errors in the estimates of b_{13} and b_{23}, but if these errors are small, β_{13} and β_{23}, and consequently the other coefficients, will be little affected. However, if one finds that the other coefficients oscillate or change markedly following the first iteration, one would have reason to suspect the model specification.

Some Empirical Results

The multicollinearity problem previously discussed is illustrated in the following regressions, based on Canadian time series [2]:

$$\begin{aligned} PB' = 4.873 &- 1.3315QB' - 0.0508QP' - 256.6775YI \\ &+ 0.3789X_2 + 0.0205T \end{aligned} \tag{13}$$

Standard errors:	(0.11)	(0.12)	(142.27)	(0.07)	(0.004)
F values:	(143.53)	(0.17)	(3.23)	(26.02)	(22.80)

$$R^2 = 0.995 \qquad F_{0.05} = 4.54 \qquad F_{0.01} = 8.68$$

and

$$\begin{aligned} PP' = 2.894 &- 0.5239QB' - 0.6250QP' \\ &+ 390.7281YI + 0.7499X_2 + 0.0035T \end{aligned} \tag{14}$$

Standard errors:	(0.22)	(0.24)	(279.40)	(0.15)	(0.008)
F values:	(5.76)	(6.69)	(1.96)	(26.44)	(0.17)

$$R^2 = 0.885 \qquad F_{0.05} = 4.54 \qquad F_{0.01} = 8.68$$

where

PB' are logs of the ratios of beef prices to the consumer price index, excluding beef and pork [2];
PP' are logs of the ratios of pork prices to the consumer price index, excluding beef and pork [2];
QB' are logs of beef consumption per adult equivalent (see Prais and Houthakker [5] for calculation of adult equivalents);
QP' are logs of pork consumption per adult equivalent;
YI are reciprocals of income per capita (constant 1949 dollars);
X_2 equals 1 for time period 1935–1939,
equals 0 for time period 1949–1964, excluding 1952; and
t equals time (1 in 1935, . . . , 30 in 1964).

These results reflect high intercorrelation between the income and time variables ($r = -0.97$), in the coefficients of YI, both of which are statistically insignificant, and one of which—equation (14)—has the wrong sign. Consequently, the method described above is used to estimate price and income elasticities of demand for beef and pork in Canada. The cross-section data used are from the 1957 D.B.S. Family Expenditure Survey, which provides information on incomes of 1,667 families, along with their expenditures on beef and pork.[1]

The procedure described in the section entitled "Solution" is followed to obtain the results in Table 1. These results differ substantially between β_{13} and β_{23}. The income coefficient in the beef equation (β_{13}) changes very little and converges very quickly under iteration. On the other hand, β_{23} changes substantially in the second round of the iteration procedure and continues to oscillate through the sixth round of iteration. This suggests that there is some inconsistency between the cross-section and the time-series

Table 1. Values of income coefficients by iteration round

Income coefficient	Iteration round					
	1	2	3	4	5	6
b_{13}	−176.8978	...unchanged under iteration...				
b_{23}	−120.7729	...unchanged under iteration...				
β_{13}	−241.6747	−242.6393	−241.9965	−242.0168	−242.0168	−242.0168
β_{23}	−168.1598	−136.0274	−137.6370	−137.7375	−137.2121	−137.3410

[1] I am grateful to Miss I. McWhinney of the Dominion Bureau of Statistics and to Mr. F. Sheffrin of the Department of Agriculture, Economics Division, for making these data available.

results for pork and leads us to conclude that the model specified is probably better suited to beef than to pork.

Account is also taken of autocorrelated residuals by following the maximum-likelihood procedures of Hildreth and Lu [1], and our final two equations are

$$(15)\qquad PB' = 5.0231 - 1.3528QB' - 0.0711QP' - 247.8943YI + 0.3798X_2 + 0.0212T$$

Standard errors:	(0.10)	(0.12)	(0.04)	(0.003)
F values:	(177.78)	(0.37)	(101.2)	(66.15)

$$F_{0.05} = 4.75 \qquad F_{0.01} = 9.33$$

$$(16)\qquad PP' = 3.63000 - 0.4704QB' - 0.6178QP' - 157.8262YI + 0.4690X_2 - 0.0050T$$

Standard errors:	(0.20)	(0.27)	(0.12)	(0.008)
F values:	(3.20)	(5.09)	(14.44)	(0.40)

$$F_{0.05} = 4.75 \qquad F_{0.01} = 9.33$$

Although the standard errors of β_{13} and β_{23} are not obtained, these coefficients are derived from the cross-section income coefficients whose F values are 64.27 for the beef equation and 18.81 for the pork ($F_{0.01}=6.66$). These reduced-form equations then yield the following structural coefficients:

$$b_{11} = -\ 0.77, \qquad b_{21} = +\ 0.59,$$
$$b_{12} = +\ 0.089, \qquad b_{22} = -\ 1.69,$$
$$b_{13} = -176.90, \qquad b_{23} = -120.77,$$
$$b_{14} = +\ 0.017, \qquad b_{24} = -\ 0.021.$$

Therefore, our point estimates of the direct price elasticities of demand are -0.77 for beef and -1.69 for pork. The more elastic demand for pork is due in part to lower levels of consumption per adult equivalent, so that given absolute increases in consumption represent larger relative increases, and in part to the more frequent purchase of pork by relatively low-income and price-conscious consumers. In addition, changes in beef prices have a much greater effect on pork consumption than vice versa. This is shown by the differences in cross price elasticities of demand (0.09 for beef and 0.59 for pork). In other words, a 1-percent increase in the price of pork increases the consumption of beef per adult equivalent by only 0.1 percent, whereas the same relative increase in the price of beef increases pork consumption by 0.6 percent. The income elasticities of demand can be estimated from b_{13} and b_{23}. These elasticities vary inversely with the level of income in this model and are estimated to have declined over the 1953–1964 period from 0.34 to 0.15 for beef and from 0.23 to 0.10 for pork. Finally,

the coefficients b_{14} and b_{24} show the secular trends in consumption per adult equivalent (upward at about 2 percent per year for beef, but downward at about the same rate for pork).

Appraisal of these results and of the iterative procedure on which they are based is facilitated by the accompanying scatter diagrams (Figs. 1 and 2), which show the goodness of fit of our final equations. As can be seen,

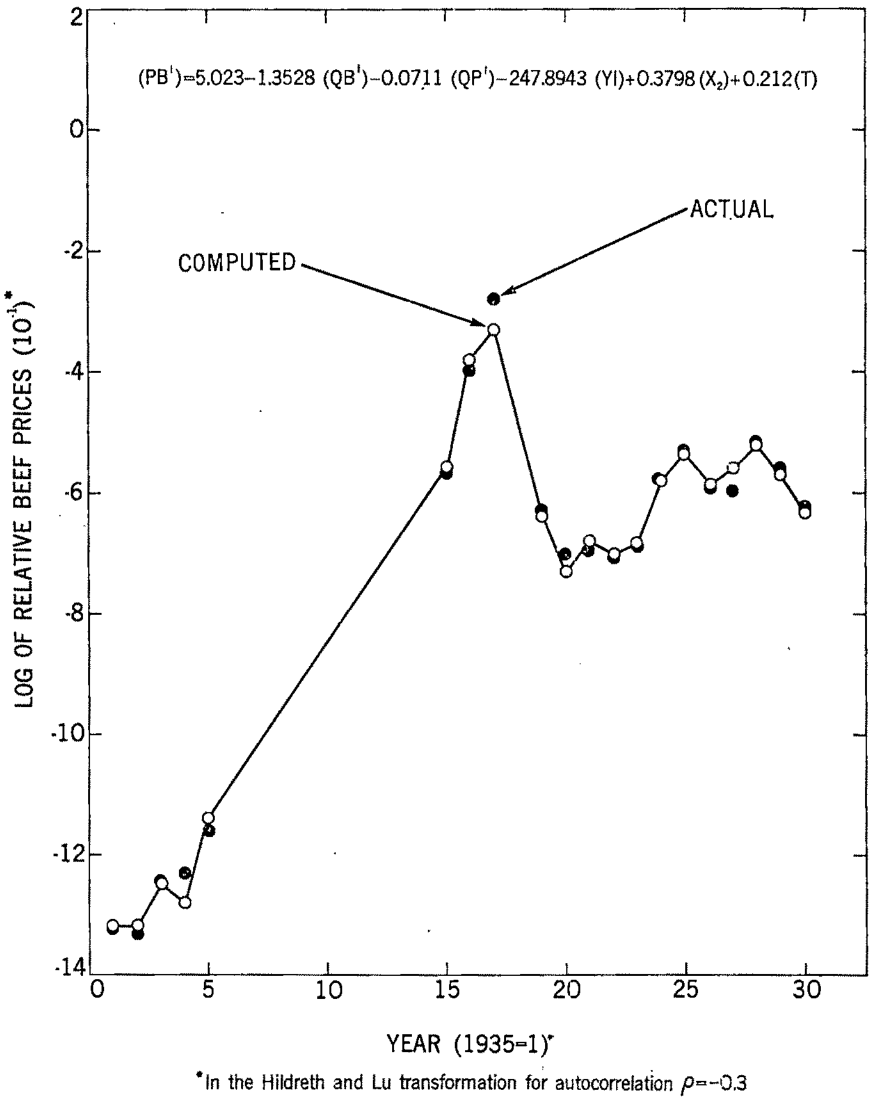

Figure 1. Actual and computed values of beef prices

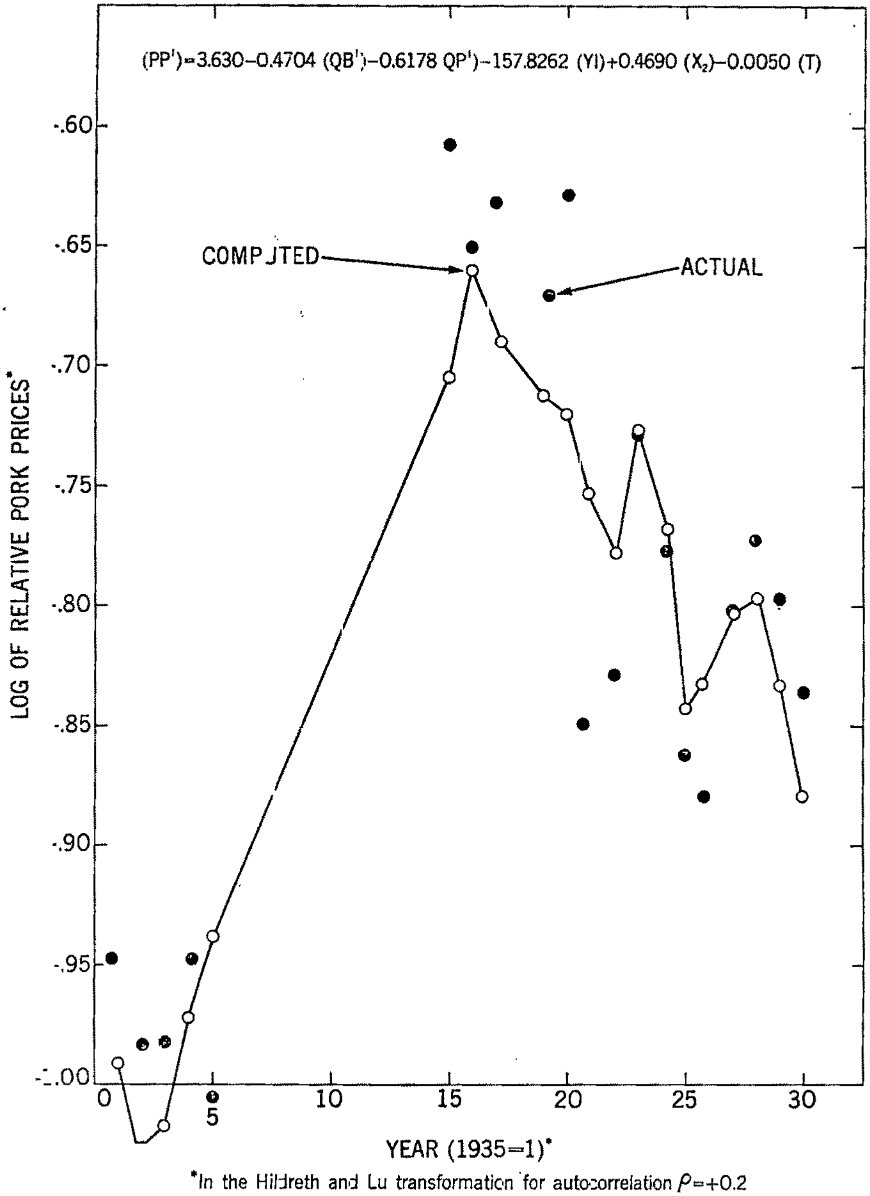

Figure 2. Actual and computed values of pork prices

the beef equation is an extremely good fit, accurately predicting both the level of, and changes in, beef prices from year to year. The pork equation is less satisfactory, thus confirming the conclusion previously drawn from the results yielded by our iteration procedure.

References

[1] HILDRETH, C., AND J. Y. LU, *Demand Relations with Autocorrelated Disturbances*, Michigan Agr. Exp. Sta. Tech. Bul. 270, Nov. 1960.

[2] HOLMES, R. A., *Estimation of Demand Elasticities for Substitute Food Products*, Agr. Econ. Res. Council of Canada, Pub. 3, 1966.

[3] KUH, E., AND J. R. MEYER, "How Extraneous Are Extraneous Estimates?" *Rev. Econ. and Stat.* 39: 380–393, Nov. 1957.

[4] MEINKEN, K. W., A. S. ROJKO, and G. A. King, "Measurement of Substitution in Demand from Time Series Data: A Synthesis of Three Approaches," *J. Farm Econ.* 38: 711–135, Aug. 1956.

[5] PRAIS, S. J., AND H. S. HOUTHAKKER, *The Analysis of Family Budgets*, Cambridge (England), At the University Press, 1955.

[6] STONE, RICHARD, *The Measurement of Consumers' Expenditure and Behaviour in the United Kingdom: 1920–1938*, Cambridge (England), At the University Press, 1954.

[7] WORKING, E. J., *The Demand for Meat*, Chicago, University of Chicago Press, 1954.

Simulation as a Method of Appraising Farm Programs

FRED H. TYNER AND LUTHER G. TWEETEN*

Simulation has been used extensively in the management sciences as a complement to more conventional methods of analysis. The procedure has also been applied in analyses of various sectors of the agricultural industry. Simulation can include time lags, nonlinearities, and recursive or reactive effects—without the restrictive assumption of an "optimum" solution. Consequently, it should find increasing application in the study of the effects of farm program alternatives. Simulation is used in this article to portray the workings of an economic model of the U.S. agricultural industry for the years 1930–1960. One simulation describes the levels of key dependent variables throughout the period, as a measure of the model's predictive ability. These results are used to evaluate a second simulation, which assumes no government diversions of commodities or cropland acreage and no payments to farmers.

THE emergence of the urban–industrial sector as a dominant force in social, political, and economic matters poses important issues for agriculture. One issue of concern in a society that is increasingly urban–industrial is the impact on the farm sector of nonfarm inflation, economic growth, and changes in technology. Another issue relates to commodity programs. Society would like for these programs to pass tests of equity and efficiency. The programs clearly fail the equity test—benefits primarily go to well-to-do farmers. There is need to determine whether these programs also fail the efficiency test. That is, do they slow needed labor adjustments and result in high farm production costs?

The principal purpose of this article is to present a methodology that can be used to study issues of farm–nonfarm interaction such as those posed above. A mathematical model is formulated and used to simulate the operation of the farm economy. The model is then used to illustrate the levels of prices, output, input, and efficiency in agriculture in the absence of commodity programs. The illustrations provide tentative hypotheses about the impact of commodity programs on farming efficiency. The results from the simulation model that focus on the second area of concern—the impact on the farm economy of changes in nonfarm prices, economic growth, and technology—are shown elsewhere [5].

The first section of this article briefly describes the construction of an aggregate economic model depicting agricultural decision-making, pro-

* Appreciation is extended to Dr. Gene Sullivan (L.S.U.) and unknown but extremely helpful reviewers for this journal for their critical appraisal of a much longer earlier draft of this paper.

FRED H. TYNER *is assistant professor of agricultural economics at Louisiana State University.* LUTHER G. TWEETEN *is professor of agricultural economics at Oklahoma State University.*

duction, and disposition. In the second section, the recursive economic model is used to simulate[1] values of farm variables over the 1930–1960 period to analyze the long-run, cumulative effects of selected changes in the data. The simulation process used is deterministic rather than stochastic.

The Recursive Economic Model

Relations between variables in agriculture and between agriculture and the nonfarm sector are complex and dynamic and are not always suited to analysis by conventional optimizing quantitative techniques. Quantitative procedures are needed which can include time lags, nonlinearities, and secondary and tertiary effects over a reasonably long period of time. The simulation procedure meets these requirements and allows the recursive aspects of the agricultural processes to be most effectively portrayed.

This article should be evaluated critically for several reasons. The model used is highly aggregative. There is a shortage of farm policy variables and explanatory variables, which restricts the usefulness of equations for answering specific questions of serious consequence. Research results obtained in the preparation of this article indicate that a more detailed model should provide a reasonable means of incorporating nonfarm variables into an analysis of the farm sector. Such a broad representation appears to be necessary for evaluation of proposed agricultural programs.

The model to be estimated is first presented in terms of a simple flow diagram (Fig. 1). This type of diagram is the initial step in formulating the model and in writing the computer program to perform the calculations. Block *A* (identified to the left of the first rectangular block of Fig. 1) consists of a set of behavioral equations and identities. These relations comprise the "pre-input" portion of the model and describe the decisions which influence the levels of inputs entering in the succeeding phase. These variables are expectation variables; that is, estimated values are used, since decisions are presumably made at the beginning of each year. Variables for which expected (estimated) values are obtained are (1) acres of crops used for cropland in year t, (2) crop and livestock inventory at the beginning of year $t + 1$, (3) stock of productive assets at the beginning of year $t + 1$, (4) purchases of machinery during year t, (5) stock of machinery at the beginning of year $t + 1$, (6) price of real estate during year t, and (7) total value of real estate during year t. Identities define average levels of crop and livestock inventory, stock of productive assets, and stock of machinery.

The estimates from block *A* feed into various equations in block *B*, either directly or indirectly. Block *B*, which can be called the "input" portion of the model, provides estimates of the levels of nine agricultural

[1] Various authors have discussed simulation and its applications [1, 2, 3].

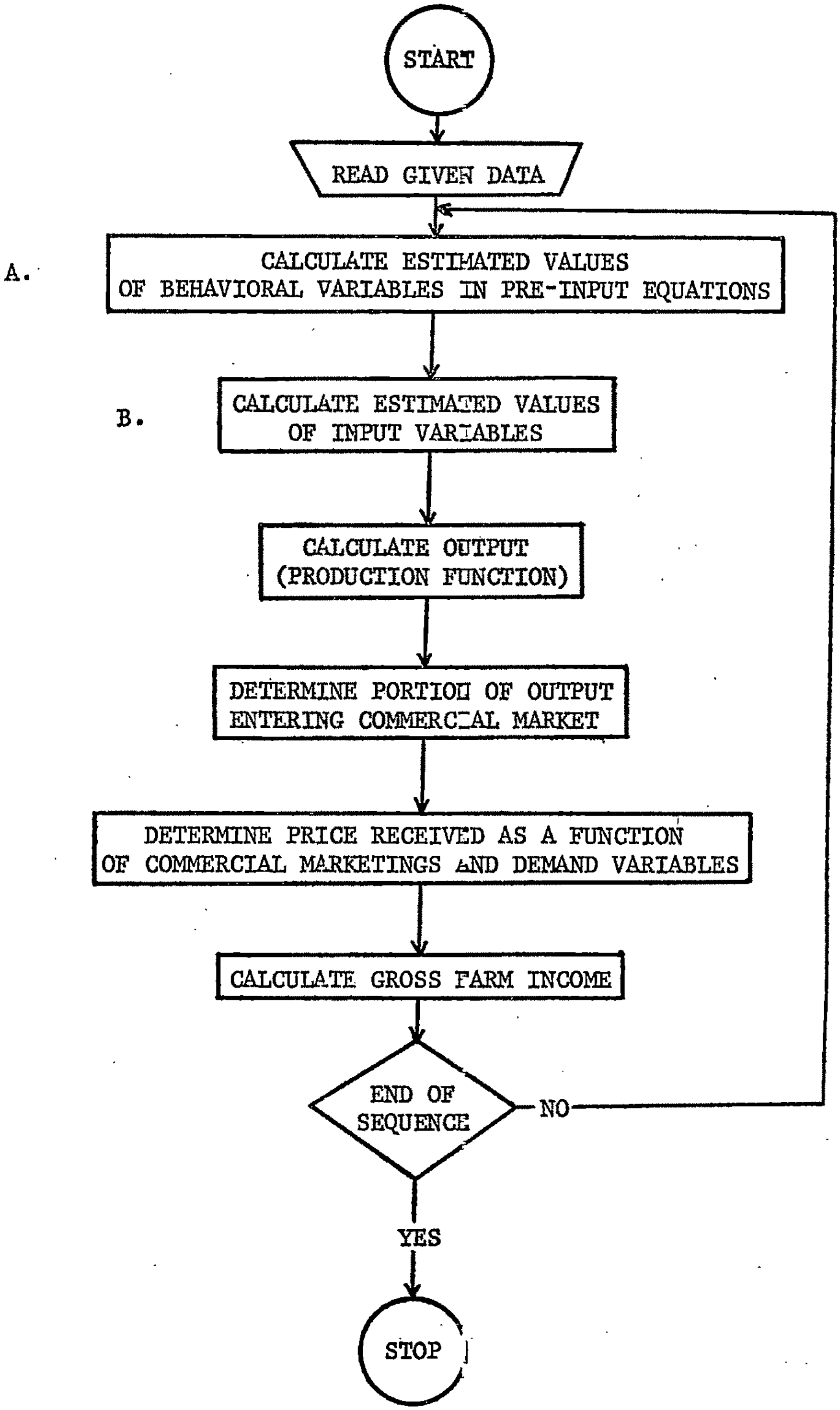

Figure 1. Generalized flow diagram of the simulation model

input groups: (1) expenditures for fertilizer and lime, (2) feed, seed, and livestock expenditures, (3) labor expense, (4) machinery ownership expense, (5) real estate expense, (6) fuel and machinery operating charges, (7) miscellaneous current operating expenses, (8) interest on crop and livestock inventories, and (9) real estate taxes.

The final portion of the model is the "output" phase. All of the estimates from block *B* feed into the appropriate production function (a separate function is presented for the years 1930–1941, 1942–1951, and 1952–1960) as the next step, and the estimated output for year *t* results. The commercial market quantity is defined as farm output minus (1) home consumption, (2) changes in inventories on farms, and (3) government diversions.[2] The aggregate commodity demand function is presented next, with the quantity demanded dependent on commercial marketings (from the preceding equation) and exogenous data on population, income, and prices of other consumer goods. The final equation specifies gross farm income as a function of the quantity of commercial marketings, prices received by farmers, and government payments to farmers.

This completes the cycle for one year, and the simulation begins at block *A* for the next cycle, using both actual data and estimates from the preceding cycle (as will be explained in detail later) until the desired number of years have been simulated.[3]

Pre-input equations

All equations for this portion of the model were estimated in linear form by the use of least-squares regression techniques. Dependent variables are as follows:

AC_t is the acreage of cropland to be used for crops in the current year;

CLI_{t+1} is the crop and livestock inventory at the end of the current year (beginning of next year);

SP_{t+1} is the stock of productive assets at the end of the current year;

PUR_t is purchases of machinery during the current year;

SM_{t+1} is the stock of machinery at the end of the current year;

PRE_t is the price of real estate during the current year;

VRE_t is the total value of real estate for the current year; and

$CLIM_t$, SPM_t, and SMM_t are average levels, defined as equal to one-half of beginning plus ending inventories.

Independent (explanatory) variables that are not lagged values of dependent variables described above are as follows:

ADIV is the number of acres diverted from production by government programs;

---

[2] *Government diversions* refers to removals of commodities from the commercial market by the Commodity Credit Corporation.

[3] For a detailed description of method and data, see Tyner [5].

PF is the index of prices paid by farmers for fertilizer materials;
PR is the index of prices received by farmers;
GFI is gross farm income; and
OUT is the value of farm output.

Estimated equations are presented in Table 1. Equation (1.1) is for estimating cropland acreage through 1955. Equation (1.2) estimates the same variable after 1955, when effective acreage diversion programs were in force. Machinery purchases are also estimated by two separate equations (4.1 and 4.2), depending on whether gross farm income in the previous year was decreasing or increasing. In equation (4.1), $GFI_{t-1} > GFI_{t-2}$ (increasing income), and in equation (4.2), $GFI_{t-1} < GFI_{t-2}$ (decreasing income). Other equations in Table 1 are self-explanatory.

Table 1. Least-squares estimates of pre-input equations[a]

Equation number	Estimated equation[b]	R^2
(1.1)	$\widehat{AC}_t = 87.572 + \underset{(4.9)^{**}}{0.64625AC_{t-1}} + \underset{(0.32)}{0.00003SP_t} + \underset{(1.73)}{0.20668PF_{t-1}}$	
	$+ \underset{(3.11)^{**}}{0.23255PR_{t-1}}$	0.760
(1.2)	$\widehat{AC}_t = -161.306 - \underset{(-4.67)^{**}}{0.09227ADIV_t} + \underset{(0.84)}{0.07881AC_{t-1}}$	
	$+ \underset{(3.06)}{0.02204SP_t} + \underset{(2.43)}{2.67889PF_{t-1}} + \underset{(0.01)}{0.00690PR_{t-1}}$	0.996
(2.1)	$\widehat{CLI}_{t+1} = 5421.775 + \underset{(1.38)}{0.35045CLI_t} - \underset{(-0.56)}{0.02922GFI_{t-1}}$	
	$+ \underset{(2.17)^{*}}{0.34221OUT_{t-1}}$	0.816
(3.1)	$\widehat{SP}_{t+1} = -2552.222 + \underset{(2.99)^{**}}{0.30869GFI_{t-1}} + \underset{(22.75)^{**}}{0.95046SP_t}$	0.973
(4.1)	$\widehat{PUR}_t = -529.777 + \underset{(5.46)^{**}}{0.08058GFI_{t-1}}$ (increasing *GFI*)	0.665
(4.2)	$\widehat{PUR}_t = -1320.573 + \underset{(18.79)^{**}}{0.10708GFI_{t-1}}$ (decreasing *GFI*)	0.967
(5.1)	$\widehat{SM}_{t+1} = -175.084 + \underset{(12.63)^{**}}{0.84260PUR_t} + \underset{(53.72)^{**}}{0.86576SM_t}$	0.996
(6.1)	$\widehat{PRE}_t = -5.314 + \underset{(3.61)^{**}}{0.00042GFI_{t-1}} + \underset{(17.05)^{**}}{0.95482PRE_{t-1}}$	0.936
(7.1)	$\widehat{VRE}_t = -3253.315 + \underset{(69.75)^{**}}{754.84551PRE_t}$	0.994

[a] Annual data, 1930–1960. Equation (1.2) uses data for 1956–1964.
[b] Figures in parentheses are calculated *t*-values, with significance levels indicated by *(5%) and **(1%).

Table 2. Least-squares estimates of input equations[a]

Equation number	Estimated equations[b]	R^2
(8.1)	$\widehat{FL}_t = 584.5834 - \underset{(-2.33)^{*}}{4.11854PF_{t-1}} - \underset{(-0.22)}{0.00048GFI_{t-1}}$	
	$+ \underset{(15.86)^{**}}{0.88698FL_{t-1}}$	0.992
(9.1)	$\widehat{FSL}_t = -66.442 + \underset{(2.42)^{*}}{0.04534CLIM_t} + \underset{(14.26)^{**}}{0.88516FSL_{t-1}}$	0.984
(10.1)	$\widehat{TFLF}_t = 11618.758 - \underset{(-10.28)^{**}}{0.41963SMM_t}$	
	$- \underset{(-2.64)^{*}}{8.2967}(1 - 5U_{t-1})(PNF_{t-1})^{c}$	0.923
(11.1)	$\widehat{XLT}_t = -4544.288 + \underset{(29.16)^{**}}{2.65069TFLF_t}$	0.967
(12.1)	$\widehat{XM}_t = 121.47680 + \underset{(99.92)^{**}}{0.23987SMM_t}$	0.997
(13.1)	$\widehat{RE}_t = -2256.27 + \underset{(5.61)^{**}}{13.22438T_t} + \underset{(2.74)^{*}}{0.00474VRE_t}$	0.844
(14.1)	$\widehat{FOE}_t = 7732.539 - \underset{(-4.80)^{**}}{10.17682AC_t} + \underset{(11.28)^{**}}{0.11792SMM_t}$	
	$- \underset{(-14.26)^{**}}{27.6532PMS_{t-1}}$	0.986
(15.1)	$\widehat{XMIS}_t = 1273.4703 + \underset{(10.37)^{**}}{0.01771SPM_t} - \underset{(-3.68)^{**}}{15.6162PFS_{t-1}}$	0.962
(16.1)	$\widehat{XINT}_t = 4.4849 + \underset{(21.44)^{**}}{0.06153CLIM_t}$	0.941
(17.1)	$\widehat{RET}_t = (TAX_t)(VRE_t)$ (Identity)	—

[a] Annual data, 1930–1960.
[b] Figures in parentheses are calculated t-values, with significance levels indicated by *(5%) and **(1%).
[c] The variable $(1 - 5U_{t-1})$ becomes zero and removes the influence of the nonfarm-wage rate when unemployment reaches 20 percent.

function for each of three time periods, (2) an identity for the portion of output entering the commercial market, (3) a behavioral commodity demand equation (at the farm level), and (4) a gross farm income equation.

The production functions[4] are as follows

[4] Estimation of production elasticities and subsequent specification of the production functions are explained by Tyner and Tweeten [6, 7]. The production functions were not fitted directly but were constructed after separate estimation of each individual production elasticity for the years indicated.

$$(18.1)\quad \widehat{OUT}_t(1930\text{–}1941) = 7.64468FL_t^{0.02648}FSL_t^{0.06165}XLT_t^{0.34777} \cdot XM_t^{0.06056}RE_t^{0.23619}FOE_t^{0.06513} \cdot XMIS_t^{0.07550}XINT_t^{0.04587}RET_t^{0.03861}$$

$$(18.2)\quad \widehat{OUT}_t(1942\text{–}1951) = 17.56649FL_t^{0.02885}FSL_t^{0.08766}XLT_t^{0.34458} \cdot XM_t^{0.07768}RE_t^{0.14837}FOE_t^{0.06901} \cdot XMIS_t^{0.05133}XINT_t^{0.04441}RET_t^{0.02112}$$

$$(18.3)\quad \widehat{OUT}_t(1952\text{–}1960) = 7.52389FL_t^{0.04325}FSL_t^{0.08862}XLT_t^{0.28983} \cdot XM_t^{0.09408}RE_t^{0.23816}FOE_t^{0.10321} \cdot XMIS_t^{0.07703}XINT_t^{0.04112}RET_t^{0.03542}$$

Commercial marketings are defined as farm output minus the sum of home consumption, changes in inventories on farms, and government diversions through the activities of the Commodity Credit Corporation. The identity is

$$(19.1)\qquad \widehat{CMQ}_t = \widehat{OUT}_t - HC_t - CIF_t - GD_t,$$

where

CMQ is commercial market quantity,
HC is home consumption,
CIF is change in inventories on farms, and
GD is government diversions.

An aggregate commodity demand equation was synthesized, based on estimates of demand, income, and other-price elasticities selected from numerous published estimates. Variables included in the initial synthesized equation are *PR* (prices received), *CMQ* (commercial market quantity), *YD* (disposable income), *CPI* (consumer price index), and *POP* (population). Coefficients were calculated for quantity (*CMQ*), income (*YD*), and other prices (*CPI*) to provide the following elasticities:

$E_{d_p} = -0.30$ (price elasticity of demand of commercial market quantity);
$E_{d_y} = 0.25$ (income elasticity of demand); and
$E_{d_{p'}} = 0.05$ (elasticity of demand with respect to prices of other consumer goods).

Thus, the partially formulated equation is

$$(20.1)\quad PR_t = -\ 0.01121CMQ_t + 0.05298YD_t + 0.14582CPI_t + Z,$$

where Z is the unexplained portion of *PR*. To complete specification of the equation, Z is regressed on population (*POP*) and a dummy variable (*D* equals one for the years 1942–1947 and zero elsewhere) by autoregressive

least squares.[5] The result is equation (20.2), with PR again expressed as the dependent variable:

$$(20.2)\quad \widehat{PR}_t = -44.29011 - 0.01121CMQ_t + 0.05298YD_t + 0.14582CPI_t + 0.40326(PR_{t-1} + 0.01121CMQ_{t-1} - 0.05298YD_{t-1} - 0.14582CPI_{t-1} - 2.2944249POP_{t-1}) + 2.2944249POP_t + 24.18D_t.$$

Calculated t-values for the estimated autocorrelation coefficient (0.40326) and the coefficient of POP_t are 14.85 and 55.53.

Gross farm income is the final quantity estimated in the model and is determined as a function of the quantity of commercial marketings (CMQ), the level of prices received by farmers (PR), and government payments to farmers (GP). Estimation of the coefficients by least squares resulted in the equation

$$(21.1)\quad \widehat{GFI}_t = 1805.5666 + \underset{(0.64)}{0.35663GP_t} + \underset{(32.16)^{**}}{1.30360(PR_t/100)(CMQ_t)}$$

$$(R^2 = 0.973).$$

Summary of the model

The purpose of this model is to provide a quantitative economic description of the activity of the agricultural sector, and the interaction of this sector with the nonfarm sector. Interaction with the nonfarm sector is most readily observable through the demand for farm products, level of unemployment, government payments to farmers, government diversions of cropland, government diversions of production, prices paid by farmers for inputs, and prices received by farmers.

The model assumes that supplies of items used by farmers in production and purchased from the nonfarm sector are available in any quantity at the prevailing price, that is, that the supply of nonfarm-produced inputs is perfectly elastic. The entire model is recursive, with estimated values of certain variables in year t used in decision-making for year $t + 1$.

Figure 2, which shows the operation of the simulation model for one year (1930), is included to provide a more detailed explanation of the simulation procedure. Variables which have an asterisk (*) above them are actual values read into the computer initially. A plus sign (+) above the variable name indicates that actual data were used for 1929, with the values of the variable for subsequent years being simulation estimates from the preceding year. A short arrow (↓) above a variable indicates that its numerical value is calculated in the *same* iteration.

[5] See Ladd and Martin [4] for a discussion of autoregressive least squares.

PRE-INPUT

$$\mathrm{AC}_{30} = f(\overset{+}{\mathrm{AC}}_{29}, \overset{*}{\mathrm{SP}}_{30}, \overset{*}{\mathrm{PF}}_{29}, \overset{+}{\mathrm{PR}}_{29})$$

$$\mathrm{CLI}_{31} = f(\overset{+}{\mathrm{OUT}}_{29}, \overset{+}{\mathrm{GFI}}_{29}, \overset{*}{\mathrm{CLI}}_{30})$$

$$\mathrm{CLIM}_{30} = (\overset{\downarrow}{\mathrm{CLI}}_{31} + \overset{*}{\mathrm{CLI}}_{30})(.5)$$

$$\mathrm{SP}_{31} = f(\overset{+}{\mathrm{GFI}}_{29}, \overset{*}{\mathrm{SP}}_{30})$$

$$\mathrm{SPM}_{30} = (\overset{\downarrow}{\mathrm{SP}}_{31} + \overset{*}{\mathrm{SP}}_{30})(.5)$$

$$\mathrm{PUR}_{30} = f(\overset{+}{\mathrm{GFI}}_{29})$$

$$\mathrm{PRE}_{30} = f(\overset{+}{\mathrm{PRE}}_{29}, \overset{+}{\mathrm{GFI}}_{29})$$

$$\mathrm{SM}_{31} = f(\overset{\downarrow}{\mathrm{PUR}}_{30}, \overset{*}{\mathrm{SM}}_{30})$$

$$\mathrm{SMM}_{30} = (\overset{\downarrow}{\mathrm{SM}}_{31} + \overset{*}{\mathrm{SM}}_{30})(.5)$$

$$\mathrm{VRE}_{30} = f(\overset{\downarrow}{\mathrm{PRE}}_{30})$$

INPUT

$$\mathrm{FL}_{30} = f(\overset{*}{\mathrm{PF}}_{29}, \overset{+}{\mathrm{GFI}}_{29}, \overset{+}{\mathrm{FL}}_{29})$$

$$\mathrm{FSL}_{30} = f(\overset{\downarrow}{\mathrm{CLIM}}_{30}, \overset{+}{\mathrm{FSL}}_{29})$$

$$\mathrm{TFLF}_{30} = f(\overset{\downarrow}{\mathrm{SMM}}_{30}, \overset{*}{\mathrm{U}}_{29}, \overset{*}{\mathrm{PNF}}_{29})$$

$$\mathrm{XLT}_{30} = f(\overset{\downarrow}{\mathrm{TFLF}}_{30})$$

$$\mathrm{XM}_{30} = f(\overset{\downarrow}{\mathrm{SMM}}_{30})$$

$$\mathrm{RE}_{30} = f(\overset{\downarrow}{\mathrm{VRE}}_{30}, \overset{*}{\mathrm{T}}_{30})$$

$$\mathrm{FOE}_{30} = f(\overset{\downarrow}{\mathrm{AC}}_{30}, \overset{\downarrow}{\mathrm{SMM}}_{30}, \overset{*}{\mathrm{PMS}}_{29})$$

$$\mathrm{XMIS}_{30} = f(\overset{\downarrow}{\mathrm{SPM}}_{30}, \overset{*}{\mathrm{PFS}}_{29})$$

$$\mathrm{XINT}_{30} = f(\overset{\downarrow}{\mathrm{CLIM}}_{30})$$

$$\mathrm{RET}_{30} = (\overset{\downarrow}{\mathrm{VRE}}_{30})(\overset{*}{\mathrm{TAX}}_{30})$$

$$\mathrm{OUT}_{30} = f(\overset{\downarrow}{\mathrm{INPUTS}}_{30})$$

$$\mathrm{CMQ}_{30} = \overset{\downarrow}{\mathrm{OUT}}_{30} - \overset{*}{\mathrm{HC}}_{30} - \overset{*}{\mathrm{CIF}}_{30} - \overset{*}{\mathrm{GD}}_{30}$$

$$\mathrm{PR}_{30} = f(\overset{\downarrow}{\mathrm{CMQ}}_{30}, \overset{*}{\mathrm{POP}}_{30}, \overset{*}{\mathrm{YD}}_{30}, \overset{*}{\mathrm{CPI}}_{30}, \mathrm{D}_{30})$$

$$\mathrm{GFI}_{30} = f(\overset{*}{\mathrm{GP}}_{30}, \overset{\downarrow}{\mathrm{CMQ}}_{30}, \overset{\downarrow}{\mathrm{PR}}_{30})$$

(Iteration for 1931, etc.)

Figure 2. Schematic diagram showing operation of the simulation model for one year (1930). (See text for explanation of symbols above variable names. "Hats" above variables have been omitted to minimize clutter.)

Simulation Analysis

The sequence of model development involved (1) estimation of coefficients for the individual equations in the model and (2) trial runs to determine how well estimates derived from the simulation procedure compared with actual data series. The trial runs were to test the predictive

ability of the original model prior to simulation analysis of the operation of the farm economy under alternative situations. Testing of the simulation model reflects the ability of the model to "predict" what has already occurred. What we desire to know, however, is what *would* have occurred under alternative conditions. It should be noted that results are derived from structural relationships in the presence of variables whose effects are to be determined. The possibility that this could induce a circularity within the model should be recognized.

In order to demonstrate the output of the model used, we present the results of two simulations.[6]

Simulation I is the original model simulated over the period 1930–1960 with no changes in data or parameters (that is, the final trial run). For this simulation, estimated values of endogenous variables in the model were plotted against actual values for the 1930–1960 period. Although the graphs of all variables were too numerous to include, the computed and observed data for gross income from Simulation I are shown in Figure 3. Gross income was selected because it is an end product, computed from all equations in the model, and hence appears to be the most appropriate single test of the predictive ability of the model. Even though gross income appears to be predicted with a reasonable degree of accuracy, this fact does not necessarily mean that the model is sufficiently structural to predict accurately the effect of changes in specific parameters.

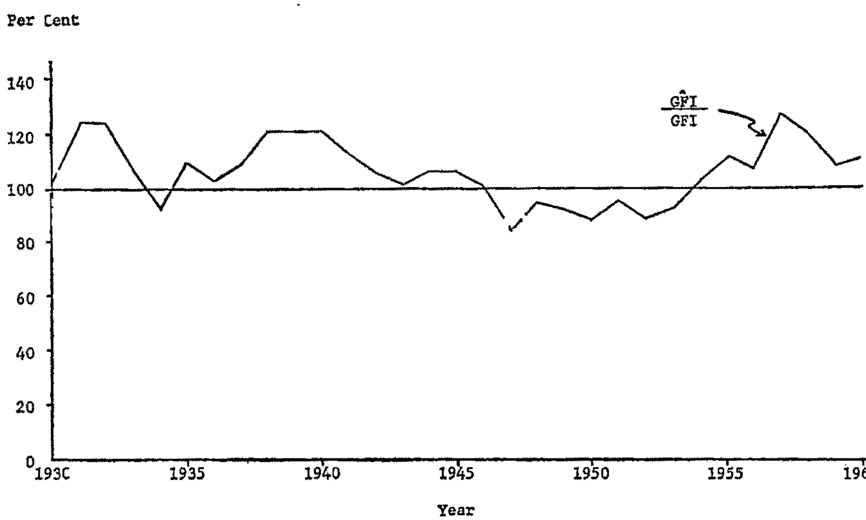

Figure 3. Ratio of estimated gross farm income ($\hat{GFI}$) to observed gross farm income (GFI), 1930–1960

[6] For results of additional simulation runs see Tyner [5].

Thus, Simulation I provides a basis for evaluating the results of Simulation II. Simulation II assumes other than actual levels for selected variables; that is, government diversions (GD), government payments to farmers (GP), and acreage diversions (ADIV) are all set at zero levels. Predictions by Simulation II are compared to the results of Simulation I below.

Comparison of Predictions by Simulations I and II

Implications of free market conditions for agricultural prices and incomes

Because government programs and policies in the past have not resulted in complete satisfaction either to farmers or to others in the nonfarm economy, there is frequent consideration of a possible return to "free market" conditions for agriculture. Government purchase and storage of basic crops has received most of the attention of free market advocates. Simulation II shows the predicted results when there are *no* diversions of excess production, *no* acreage controls, and *no* government payments to farmers.

Effects on prices received and gross farm income.—The adverse effect on farm incomes of placing excess quantities of a commodity on the market can be estimated as a "first-order" effect by using the elasticity-of-demand formula. Such an estimate does not, however, indicate changes in resource use, nor does it picture the cumulative effects, over a period of years, of a once-and-for-all program change.

Average levels of key variables for 1930–1940, 1941–1950, and 1951–1960 are given in Tables 3 and 4. For the 1930–1960 period, estimates of prices received (*PR*) in the absence of government diversions of production, government payments, and acreage controls averaged 7.0 percent lower in Simulation II than the estimates of Simulation I. Estimates of *PR* for the most recent period (1951–1960) averaged 81.4 and 68.0, respectively, for Simulations I and II. Because of a lower level of prices received, gross farm income for 1951–1960 averaged 13 percent lower in Simulation II than was estimated in Simulation I.

Effects on net income.—Average net farm income for 1951–1960 can be calculated by subtracting the value of all inputs from gross farm income. Total inputs for the period (excluding labor) are calculated to average \$16,937.5 million. Man-hours worked averaged 12,688.7 million per year. Total labor cost is calculated by charging 85 percent of the hourly nonfarm wage as the cost of both hired and family labor. The adjusted hourly wage equals \$1.34, giving a labor cost of \$17,002.9 million. Net income is calculated to be negative (−\$6.3 billion).

Net returns to family labor, a more meaningful concept, can be calcu-

Table 3. Average levels of input use for simulations: 1930–1940, 1941–1950, and 1951–1960

Simulation		Input[a]									
		FL	*FSL*	*XM*	*RE*	*FOE*	*XMIS*	*XINT*	*RET*	Total	*TFLF*
		million 1947–1949 dollars									*thousands*
I	1930–1940	284.5	1,024.0	1,061.0	3,337.1	712.7	1,143.6	1,101.8	807.7	9,472.7	9,853.9
	1941–1950	697.2	1,739.3	1,530.1	3,514.7	1,593.7	1,358.6	1,287.0	642.8	12,363.1	8,528.3
	1951–1960	1,286.5	2,597.7	2,648.0	3,737.1	2,536.1	2,015.1	1,425.3	851.8	17,098.0	6,435.1
II	1930–1940	285.0	1,024.7	1,057.7	3,335.9	716.6	1,142.6	1,102.1	801.0	9,468.5	9,859.7
	1941–1950	699.3	1,742.4	1,522.8	3,505.4	1,608.1	1,356.3	1,287.8	625.8	12,347.9	8,541.0
	1951–1960	1,296.7	2,609.7	2,610.1	3,699.2	2,513.7	2,004.8	1,428.1	776.3	16,937.5	6,501.3

[a] Refer to text for definitions of the input variables.

Table 4. Average levels of output, prices received, and gross farm income for simulations: 1930–1940, 1941–1950, and 1951–1960

Simulation	*OUT*			*PR*			*GFI*		
	1930–1940	1941–1950	1951–1960	1930–1940	1941–1950	1951–1960	1930–1940	1941–1950	1951–1960
	million 1947–1949 dollars			*1947–1949 = 100*			*million 1947–1949 dollars*		
I	20,859.4	26,645.5	32,390.0	69.6	93.1	81.4	19,079.3	30,489.2	31,717.7
II	21,084.7	26,406.2	32,276.0	68.2	91.0	68.0	18,657.0	29,876.5	27,666.0

lated by charging only for hired labor. Approximately 27.1 percent of total man-hours worked from 1951 to 1960 was attributed to hired labor. Average hourly earnings for hired labor were $0.698. Assuming the same distribution between family and hired labor in Simulation II, average hours worked by hired labor are 3,438.6 million. The hired labor cost is thus $2,400.1 million ($0.698 × 3,438.6). Net returns to family labor (*GFI* − costs) are $8,328.4 million.

Net returns to family labor calculated in the same manner for Simulation I are $12,252.7 million. Average net returns to family labor are therefore lower by $3,924.3 million (or 32 percent) annually in the absence of the government programs. This result is consistent with other studies of farm income under a free market [8].

The effect of government programs on agricultural resource use

Effect on nonlabor resources.—The absence of government programs for diverting excess production results in an estimated average annual reduction in total input use (excluding labor) of $160.5 million for the 1951–1960 period. The machinery-stock input decreases $38 million, real estate decreases $38 million, fuel and operating expense decreases $23 million, and miscellaneous inputs decrease $11 million. Real estate tax expense decreases most, over $75 million, as a result of declining land prices in the absence of these government programs.

Inputs showing an increased use are fertilizer and lime ($9.2 million), feed, seed, and livestock ($12.0 million), and interest on crop and livestock inventories ($2.8 million).

Effects on farm labor force.—An hypothesis frequently advanced is that government programs have had an undesirable effect on the farm labor force, retarding the outflow of a resource that is conceded to be in excess. Results obtained in this simulation contradict that hypothesis. The estimated farm labor force is higher by an average of 66,200 workers in the absence of government programs than was estimated in Simulation I. This indicates that, rather than discouraging the movement of farm labor to nonfarm employment, the programs have aided or encouraged this movement, although the percentage change is small.

This favorable effect apparently occurs as a result of higher farm income when the government programs are in operation, enabling farmers to purchase additional or more efficient machinery and equipment, thereby decreasing the need for labor. Forward pricing and income security provided by programs also have encouraged substitution of capital for labor.[7] Also, the programs have increased the value of farm real estate,

[7] While results of the model tend to be consistent with these considerations, not all of the factors listed in this paragraph were explicitly included in the model.

thereby presenting a barrier to entry for new farmers. Those farmers who wish to sell their farms thus obtain a larger stake to finance the transition to nonfarm employment, with the purchases tending to be for farm enlargement rather than for new starts in farming.

The simulation model is based on past rates of labor response and hence considers adjustments to be "orderly." If there were stringent economic incentives (a higher rate of bankruptcy for farmers), farm labor would likely move out at a much faster rate. However, society would scarcely tolerate this condition.

The efficiency of the government programs versus free markets can be compared by examining the output–input ratio and the total commitment of resources to agriculture. Total input volume (with labor priced at $1 per hour) and the output–input ratio (average, 1951–1960) are $29,626.2 million and 1.09 under the free market, and $29,611.3 million and 1.09 under actual government programs (that is, Simulation I).

The tentative conclusion from the simulation analysis is that costs per dollar of farm output are as low under government programs as they would have been under free markets. In fact, the resource allocation more nearly approximates the optimum allocation of a perfect market[8] under government programs than under "free" markets. The result implies a second-best solution, however, because effective public effort to increase knowledge and decrease friction in labor markets would have led to a more nearly optimum allocation than that "coerced" by the substitution of machinery for labor and by higher land prices fostered with government programs.

Conclusions

The objective of this study was to present a mathematical model that can be used to simulate the operation of the farm economy. Although the principal purpose was methodological, the article also illustrates how some public policy issues can be examined with the model.

The procedure first entailed estimation of input demand functions. These functions determined input levels, which in turn were fed into estimated production functions. The output of the production functions, after correction for "leakages," was in turn fed into an estimated commodity demand equation. The demand equation determined prices received by farmers. Prices received by farmers, output, and direct government payments in turn determined gross farm income. Current values of prices and income received by farmers became lagged values in equations to determine input levels in the next year. This recursive process was used to simulate the operation of the farm economy for 30 years.

[8] See Tyner and Tweeten [7] for an estimated optimum allocation.

Results are presented for two simulations, covering (*a*) the 1930–1960 period, with no changes in data or parameters (Simulation I), and (*b*) implications of free market conditions for agricultural prices and incomes, and the effect of government programs on agricultural efficiency and resource use (Simulation II). Simulation I showed that the model could predict actual levels of variables with useful accuracy.

One implication of the results of Simulation II is consistent with *a priori* expectations. Removal of government programs for surplus diversion, government payments to farmers, and acreage controls indicated that farm prices and incomes would have been significantly lower in their absence.

Another result of this study was not consistent with our *a priori* expectations. More labor is present in agriculture under free markets than under government programs when supply adjustments, capital substitutions, and other secondary effects are taken into account. Farm programs appear not to have increased average costs of production nor retarded labor adjustments. This result can be viewed as tentative, subject to the limitations of the model. It may be regarded as an hypothesis in need of additional testing. Lack of data and time precluded estimations for years more recent than 1960 in the above simulations. Extension of the results to more recent years is in the first rank of needs for further research.

The aggregate economic model used in the simulation procedure is one of numerous possible formulations. Alternative formulations of the model and individual equations should considerably improve the estimates generated. Also, simulation analysis of alternative hypotheses could add to our knowledge of the operation of the agricultural economy.

References

[1] BABB, E. M., AND C. E. FRENCH, "Use of Simulation Procedures," *J. Farm Econ.* 45:876–877, Nov. 1963.

[2] CROM, RICHARD J., AND WILBUR R. MAKI, "Adjusting Dynamic Models to Improve Their Predictive Ability," *J. Farm Econ.* 47:963–972, Nov. 1965.

[3] HALTER, A. N., AND G. W. DEAN, "Use of Simulation in Evaluating Management Policies Under Uncertainty: Application to a Large Scale Ranch," *J. Farm Econ.* 47:557–573, Aug. 1965.

[4] LADD, GEORGE W., AND JAMES E. MARTIN, *Application of Distributed Lag and Autocorrelated Error Models to Short-Run Demand Analysis*, Iowa Agr. Exp. Sta. Bul. 526, May 1964.

[5] TYNER, FRED H., "A Simulation Analysis of the Economic Structure of U. S. Agriculture," unpublished Ph.D. thesis, Oklahoma State University, May 1967.

[6] TYNER, FRED H., AND LUTHER G. TWEETEN, "A Methodology for Estimating Production Parameters," *J. Farm Econ.* 47:1462–67, Dec. 1965.

[7] ———, "Optimum Resource Allocation in U. S. Agriculture," *J. Farm Econ.* 48:613–631, Aug. 1966.

[8] TWEETEN, LUTHER G., EARL O. HEADY, AND LEO V. MAYER, *"Farm Program Alternatives, Farm Incomes and Public Costs Under Alternative Programs for Feed Grains and Wheat,"* Iowa State University CAED Rep. 18, May 1963.

Effects of Nonprice Variables upon Participation in Water-oriented Outdoor Recreation

GLENN A. GILLESPIE AND DURWARD BREWER*

The increasing proportion of the population which lives and works in metropolitan areas is a primary factor in the growing demand for recreation. Recreation research concerning the allocation of land and water to meet more fully the demand for water-oriented outdoor recreation is of increasing importance as population increases. The model developed here allows appraisal of nonprice information needed by private and government decision makers in planning for recreational uses of land and water. It permits projections of recreation participation for a population of a metropolitan area by utilizing changes in the socioeconomic composition of the population as well as its size.

AS population increases and competitive pressures mount for land and water, conservation and preservation of areas for recreational uses for present and future generations becomes a national problem of increasing significance. The demand for recreation should be a major factor guiding the development of land and water resources of the nation.

Measurement of the demand for water-oriented outdoor recreation is not easily achieved. Recreation experiences are not standardized and marketed at retail as are most other commodities. Such experiences are primarily resource-oriented; thus, consumers must be attracted and transported to the recreation area or site. These characteristics of the product logically lead to the fact that free interchange of outdoor recreation in the marketplace to establish an equilibrium price does not fully exist.

Considerable research on the demand for visits to parks and other recreation areas has been conducted in recent years. A survey of the literature may be found in Stevens' recent analysis of demand for sport fishing in Oregon [4]. A few of these studies are mentioned here to place our research in perspective with respect to the objectives undertaken.

Hotelling (as reported by Prewitt [3]) proposed the method of estimating price by using travel costs derived from concentric distance zones. Clawson [2] applied this method to recreation demand, using visits to national parks. Boyet and Tolley [1] expanded the procedure developed by Hotelling and Clawson by including other variables in a multiple-regression model. Boyet and Tolley used visits by states of origin for estimating distance traveled rather than concentric zones, since population

* We should like to thank Professors O. R. Burt and J. C. Headley of the Department of Agricultural Economics, University of Missouri, for their comments and suggestions.

GLENN A. GILLESPIE *is an agricultural economist with the Economic Research Service, Natural Resource Economics Division, USDA.* DURWARD BREWER *is associate professor of agricultural economics at the University of Missouri.*

data was readily available by states. A limitation of the approach used by Hotelling and Clawson lies in the problem of dealing with variables other than those directly or indirectly associated with price. Typically, the variation from one observation to another on such variables as leisure time, family income, transfer cost, and quality variables–roads, lodging, camping, dining facilities–is not great enough to measure their net effects [4]. The difficulties involved in developing accurate population data for the concentric zones used in the Hotelling–Clawson method is one of its major disadvantages. Distance, population, and income were the significant explanatory variables used in the Boyet–Tolley analysis. The use of distance as a proxy variable permits the estimation of the influence of price on participation in recreation activity.

Approach Used and Study Area

Few researchers have used direct sampling of the population of an area in an attempt to determine the quantity of recreation demanded by that population in relation to socioeconomic characteristics. This study was not designed to estimate the influence of price on the consumption of recreational services. Rather, it concentrated on other factors affecting quantities consumed. Therefore, the sample was drawn from a single metropolitan area so that all members of the sample would be facing nearly the same price, or complex of prices, if the commodity is viewed as an aggregate of many separate but closely related services.

Because transportation costs are a major part of the cost of obtaining recreational services, the price of a bundle of recreational goods and services is the same for all consumers only if they are equidistant from that bundle of goods and services. In the sample used in this study, the assumption is met except for differences in distance among consumers within the metropolitan area. These differences are insignificant relative to total costs of transport. In contrast, any change in location involves a different set of prices associated with the same set of recreational opportunities. This suggests two methods of approach: separate price effects can be estimated for each recreational service by sampling separate locations relative to consumer residence and site of facility, or prices can be held constant by sampling from a single location and price effects not estimated at all. The latter approach was used in this study.

The increasing proportion of the population which lives and works in metropolitan areas is an important factor in the growing demand for recreation. One thousand households were sampled in the metropolitan St. Louis area. The sampling procedure used in the study was essentially that used by the United States Bureau of the Census [6], with necessary adjustment made for application of the multistage plan to metropolitan St. Louis. Household heads were interviewed to determine the socioeconomic

characteristics of the family and the family's participation in water-oriented outdoor recreation activities.[1]

Fourteen recreation activities were included in the analysis. These were swimming, water skiing, ice skating, camping, picnicking, boating, boat fishing, hunting, sight-seeing, nature walks, golfing, hiking, and "other." Activities usually not directly involving surface waters, such as hunting and golfing, were enumerated only when they were water-associated within the recreation complex.

The Model

The socioeconomic factors considered include both quantitative and qualitative variables. The standard multiple regression model thus included "zero-one" or "dummy" variables to measure net effects of qualitative characteristics of the population.[2]

The final mathematical model used to explain participation in water-oriented outdoor recreation was

$$X_1 = \beta_0 + \alpha_j + \beta_2 X_2 + \cdots + \beta_9 X_9 + e \tag{1}$$

where

X_1 is days of water-oriented outdoor recreation per year,[3]

β_0 is a constant term,

α_j is the net effect of the jth occupation with the restriction, $\alpha_1 + \alpha_2 + \cdots + \alpha_9 = 0$,

X_2 is annual family income in dollars,

X_3 is age of the head of the household,

X_4 is education of the head of the household,

[1] Since this study was conducted in a major metropolitan population adjacent to a vast rural mountainous area, there is some difficulty in extropolating results to other areas. Difficulties stem from the fact that the set of prices faced by the population are usually altered as a result of change in the location of the population relative to the sources of recreation services. In order that the study may be more fully utilized in other areas, a brief description is given of the available outdoor recreational opportunities in the vicinity of St. Louis. There are approximately 150 lakes, both private and public, ranging in size from 5 to 400 surface acres, within a 50-mile radius of the metropolitan center. Within this area, there are also numerous lakes of less than 5 acres, many undeveloped. Within one to two hours' highway travel time there are 10 major lakes in the Ozarks offering a total array of water-oriented recreational activities. Lake of the Ozarks, comprising over 59,000 acres, is one of the most highly developed lakes in the region, with most of the adjoining shore land owned and developed by private individuals. Also within less than 150 miles there are 16 well-developed state parks, two national forests (Clark and Mark Twain), hundreds of miles of natural streams and river shoreline, numerous commercial caves, campgrounds, hunting lodges, summer camps, resort motels, riding stables, canoeing access points, springs, and commercial playgrounds.

[2] See Tomek [5] for a discussion of the use of such variables.

[3] "Recreation day" is a standard unit of use consisting of a visit by one individual to an outdoor recreation development or area for recreation purposes during any portion or all of a 24-hour period measured from midnight.

X_5 is age squared,
X_6 is education squared,
X_7 is the product of income and age,
X_8 is $\begin{cases} 1 \text{ if the head of the household is female,} \\ 0 \text{ if the head of the household is male,} \end{cases}$
X_9 is $\begin{cases} 1 \text{ if the head of the household is nonwhite,} \\ 0 \text{ if the head of the household is white, and} \end{cases}$
e is the random error component.

Estimates of the parameters in equation (1) are given in Table 1.

The computer routine used in the analysis required treating occupation as a dummy variable; the category "retired" was used as the standard from which net effects were measured for other occupations. Estimates of the $\{\alpha_j\}$ were computed from this formulation by using a desk calculator, but standard errors for the estimates were not computed since the computation would have required an unwarranted effort. The standard t-ratios given in Table 1 can be used to test the hypothesis that the occupation in question has the same net effect as the "retired" category.

The net effects of the three qualitative variables (occupation, sex, and race) are assumed to be additive, that is, no interactions are present. Whether this assumption is valid is questionable, but the 32 parameters needed to test the hypothesis were considered excessive in light of the statistical reliability of the model.

Interpretation of Results

The net effects of any set of qualitative socioeconomic characteristics upon recreation participation can be determined by using the intercept value of 53.5 and the appropriate parameter estimates given in Table 1. That is, by using the regression coefficients of -5.86 for sex and -14.27 for race, and the appropriate values for each occupation class, the intercept values for all combinations of qualitative variables can be computed (Table 2). The net influence of the quantitative variables is indicated by the slope of the regression line.

Income and age are primary variables influencing participation in water-oriented outdoor recreational activity and are significantly interrelated. Changes in income have different effects at different age and income levels. By measuring the marginal income effect at various age levels, estimates can be obtained of the change in recreational activity in response to changes in income.

Income

To measure the net marginal income effect in recreation days, a partial derivative with respect to income is taken from estimates for equation (1) given in Table 1, which yields

Table 1. Estimates of the parameters in the statistical recreation model and averages and proportions for variables

Variable (X_k)	k	Regression coefficient	t-ratio	Mean value	Occupation	j	Net effect	t-ratio	Proportion in occupation[d]
Recreation days	1	—	—	27.3					
Income	2	− 0.001540	−1.539	$8,543.48	Professional	1	− 7.87	−3.03	0.108
Age	3	− 0.076362	−0.1249	48.27	Administrative	2	− 7.20	−3.22	0.144
Education	4	− 4.170880	−2.379	11.48	Technical	3	+ 0.85	−1.83	0.080
Age squared	5	− 0.007790	−1.227	—	Services	4	− 0.56	−2.42	0.205
Education squared	6	+ 0.218604	+2.934	—	Clerical	5	− 7.43	−2.96	0.074
Product of income & age	7	+ 0.000068	+3.739	—	Laborer	6	− 6.55	−1.34	0.155
Sex of household head	8	− 5.859799	−1.263	0.152[a]	Housewife	7	+ 6.89	−0.88	0.064
Race of household head	9	−14.272207	−3.127	0.99[b]	Unemployed	8	− 4.67	−1.39	0.011
					Retired	9	+13.44	—[c]	0.160

Constant term = 53.5 $R^2 = 0.62$ $n = 1000$

[a] Interpreted as proportion of household heads that are female.

[b] Interpreted as proportion of household heads that are nonwhite.

[c] This occupation served as base or standard. The t-ratios for the other occupations can be used to determine whether the net effect or the occupation in question differs significantly from the retired category.

[d] Occupation would enter as a weighted sum of the $\{\hat{\alpha}_j\}$: $0.108\alpha_1 + 0.114\alpha_2 + \cdots + 0.011\alpha_8 + 0.16\alpha_9$ for the prediction at the mean sample characteristic.

$$\frac{\partial X_1}{\partial X_2} = -0.00154 + 0.000068X_3. \tag{2}$$

Using different age levels in the model, we obtain the net marginal income effect in recreation days for the various age levels. As age increases, the marginal effect of income increases. Table 3 shows the numerical tabulations of the derivative from equation (2).

Table 2. Summary of intercept values for combinations of the qualitative variables in the recreation model

Occupation	Female household head		Male household head	
	Nonwhite	White	Nonwhite	White
	recreation days			
Professional	25.50	39.77	31.36	45.63
Administrative	26.17	40.44	32.03	46.30
Technical	34.22	48.49	40.08	54.35
Services	32.81	47.08	38.67	52.97
Clerical	25.94	40.21	31.80	46.07
Laborer	39.92	54.19	45.78	60.05
Housewife	40.26	54.53	46.12	60.39
Unemployed	28.70	42.97	34.56	48.43
Retired	46.81	61.08	52.67	66.44

Holding X_1 and X_2 constant at their means and substituting different age levels, we can compute the income elasticity of demand for recreation at various age levels. This varies from a low of −0.38 for household heads 20 years of age, to 1.65 for household heads 80 years of age, with an elasticity of 0.98 at the mean age of 48.27 (Table 3). Apparently income is a greater determinant of participation in outdoor recreation for older people than for younger people. This outcome is probably partially explained by the physical restrictions on the types of activity in which older people can engage. An older person may have to make a greater outlay for associated services in order to make the activity less of a physical hardship.

Table 3. Marginal income effect and income elasticity of recreation demand at various age levels

Age of household head	Marginal effect[a]	Elasticity
20	−0.18	−0.38
30	+0.50	+0.59
40	+1.18	+0.80
50	+1.86	+1.01
60	+2.54	+1.22
70	+3.22	+1.44
80	+3.90	+1.65

[a] Change in number of recreation days per $1,000 of income added.

Age

Marginal effects on rates of participation in water-oriented outdoor recreation are a function of age and income. Therefore, rates of participation for a given age level vary with different income levels.

The partial derivative of equation (1) with respect to age, on the basis of estimated parameters, is

$$\frac{\partial X_1}{\partial X_3} = -0.0764 + (-0.0156)X_3 + 0.000068X_2. \tag{3}$$

A two-way classification of equation (3) is given in Table 4, illustrating the marginal effects of age in recreation days while income and age are held fixed at various levels. Measures of elasticity with respect to age are also included; this elasticity at the mean values of the variables is 0.45. It is apparent from equation (3) that the marginal net effect of age on quantity demanded is inversely related to age itself and directly related to income.

Table 4. Net marginal effect of age and age elasticity of recreation demand at different income levels

Age / Level of income	20 years		35 years		48.27 years[a]		60 years	
	Marginal effect[b]	Elasticity	Marginal effect[b]	Elasticity	Marginal effect[b]	Elasticity	Marginal effect[b]	Elasticity
$ 1,000	−0.32	−0.23	−0.55	−0.70	−0.78	−1.37	−0.87	−1.88
3,000	−0.18	−0.13	−0.42	−0.54	−0.63	−1.11	−0.73	−1.60
5,000	−0.05	−0.03	−0.28	−0.36	−0.50	−0.88	−0.59	−1.29
10,000	+0.29	+0.21	+0.06	+0.51	−0.16	−0.28	−0.25	−0.55
15,000	+0.63	+0.46	+0.40	+0.78	+0.18	+0.32	+0.09	+0.20
20,000	+0.97	+0.71	+0.74	+0.94	+0.52	+0.91	+0.43	+0.94
25,000	+1.31	+0.96	+1.08	+1.38	+0.86	+1.52	+0.77	+1.69

[a] Average age for sample.
[b] Change in number of recreation days per added year of age of household head.

Education

The net marginal effect of education, which can be determined by taking the partial derivative with respect to years of formal education, is

$$\frac{\partial X_1}{\partial X_4} = -4.17 + 0.437X_4. \tag{4}$$

The marginal effect of education is negative up to approximately ten years of formal training and then becomes positive as the level of education increases beyond ten years. Marginal effects of education are shown in Table 5, together with elasticity measures.

Table 5. Marginal effect of education and education elasticity of recreation demand at various educational levels

Level of education	Marginal effect[a]	Elasticity
Elementary		
4	−2.42	−0.53
7	−1.11	−0.28
8	−0.67	−0.45
High school		
11	+0.64	+0.26
12	+1.08	+0.47
College		
15	+2.39	+1.31
16	+2.82	+1.64
17	+3.26	+2.02

[a] Change in number of recreation days per added year of schooling.

Applications

The above procedures can be used to determine the influence of many variables upon the demand for water-oriented outdoor recreation. The model can be used to predict the annual number of days of water-oriented outdoor recreation for a typical family with specific socioeconomic characteristics. It may be used for predictive purposes for a population of a metropolitan area by use of the mean values of the socioeconomic characteristics of the population, multiplied by the number of families of that population. Because some of the variables are nonlinear, a more accurate procedure would be to stratify the population by specific characteristics and estimate their activity by groups.

If we assume that persons with similar socioeconomic characteristics react to recreation supplies in the same manner regardless of geographic location, the general model developed here can be used with U. S. Census data to estimate the total quantity of recreation demanded in any area without resorting to a sample survey of the area. If specific socioeconomic characteristics of the population are expected to change, allowances can be made to meet the changing demand. Many projections are available for future income, population, age, and education levels. By inserting into the model projected levels of the various socioeconomic factors, we can estimate future consumption with more accuracy than by previous methods. The mode will be especially useful to planners of government-financed and local recreational areas, who must plan developments to fulfill future anticipated demands.

Projections of the magnitude of many of the significant independent variables of the model are already developed for other uses. These data for such variables as income, education, occupation, and number of people

can be used in the model to yield estimates of the quantity of recreation demanded in future time periods.

As incomes increase, education levels rise, and more people move into white collar occupations, the quantity of recreation demanded by these people will increase significantly. Estimates of these future demands are necessary for long-range development plans for our natural resources. These estimates are subject to a margin of error, just as is any projection, but they indicate a degree of reliability acceptable for planning purposes.

References

[1] BOYET, WAYNE E., AND GEORGE S. TOLLEY, "Recreation Projection Based on Demand Analysis," *J. Farm Econ.* 48:984–1001, Nov. 1966.

[2] CLAWSON, MARION, *Methods of Measuring the Demand for and Value of Outdoor Recreation*, Resources for the Future, Reprint 10, Washington, 1959.

[3] PREWITT, ROY A., "The Economics of Public Recreation: An Economic Study of the Monetary Evaluation of Recreation in National Parks," Misc. Paper, Washington, National Park Service, 1949, mimeo.

[4] STEVENS, JOE B., "Recreation Benefits from Water Pollution Control," *Water Resources Res.* 2:167–182, Second Quarter 1966.

[5] TOMEK, WILLIAM G., "Using Zero-one Variables with Time Series Data in Regression Equations," *J. Farm Econ.* 45:814–822, Nov. 1963.

[6] U.S. Department of Commerce, Bureau of the Census, *The Current Population Survey: A Report on Methodology*, Tech. Paper 7, 1963.

Efficient Equalization Funds for Farm Prices*

WILFRED CANDLER AND ALASTAIR MCARTHUR

The objective of an equalization fund is to "accept" a series of market prices over a period of time and transform these into equalized prices to farmers, so that the equalized prices have a lower variance than the original market prices. An arrangement which minimizes the variance of equalized payments for a given variance of the equalization fund is said to be efficient. The derivation of efficient funds is considered for the case where prices are independent and autocorrelated (for one year). Quantity supplied is taken to be independent of price, but price is a function of quantity. It is shown that the "instinctive" suggestion of an equalized price calculated as a moving average, with equal weights, of previous prices, is appropriate only if fluctuations in the equalization fund are of no interest.

EQUALIZATION funds have been proposed, and used, to influence the prices paid to farmers for a number of agricultural products. Where the equalized price is determined administratively, it is a common experience that equalization schemes rapidly tend to divorce the prices paid to producers from the long-term trend of world prices. Equalization schemes tend to be transformed into price-support or export-levy schemes. The records of a number of income equalization schemes for primary products have been reviewed by Bauer and Paish [1, p. 750]. These authors suggest that the political pressures likely to be encountered in any administrative price-setting procedure could be avoided by adopting a rigid mathematical function for the determination of the equalized price.

This paper considers the selection of mathematical functions for the determination of the equalized price. The functions are efficient in the sense of minimizing the variance of prices paid to farmers for given variance levels for the equalization fund. Attention is given to both independent and autocorrelated price series. In two of the cases examined, it can be shown that the expected value of the equalization fund is independent of the fund's variance.

In general, ceterus paribus, it is assumed that an equalization function which lowers the variance of both the equalized price and the equalization fund is to be preferred to a function which results in higher values of these variances.

Before considering the derivation of efficient equalization functions, we should perhaps point out that such funds are inappropriate if price variability has adverse effects on the *consumption* of the product. The essence of an equalization fund is that it "accepts" from consumers a series of pay-

* This article is complementary to one by Bauer and Paish [1].

WILFRED CANDLER *is professor of agricultural economics at Purdue University.* ALASTAIR MCARTHUR *is senior lecturer in rural education at Lincoln College, Christchurch, New Zealand.*

ments with a given variance and transforms these into a series of equalized payments to producers, where the new series of payments has a lower variance than the original series.

Thus, an equalization fund does little or nothing to reduce the variance of market prices and consequently does not reduce any difficulties arising for consumers as a result of price variability.

Notation

The notation used in this paper can be summarized as follows:

$e_i(i=1,2, \cdots)$ is the equalized price in the ith year,

$f_i(i=1,2, \cdots)$ is the net payment to the equalization fund in the ith year,

$F_i(i=1,2, \cdots)$ is the total value of the equalization fund at the end of the ith year,

f_0 is the initial value of the equalization fund,

m is the number of years over which payment is spread,

$p_i(i=1,2, \cdots)$ is the market price for the commodity in the ith year,

$q_i(i=1,2, \cdots)$ is the quantity of product produced in the ith year,

p_i, $q_i(i=0,-1, \cdots)$ are "dummy" prices and quantities used in the equalization function to define the equalized price in the first few years,

$w_j(j=0, 1, 2, \cdots, m)$ is the proportion of the price received, p_i, paid out by the equalization function j years after receipt (that is, $w_0=0.7$ means that 70 percent of the price of the product is included in the equalized price for the year in which it is received, and $w_3=0.1$ means that 10 percent of the price of the product is included in the equalized price three years after it is received),

ϕ is the relative increase in the variance of the equalization fund which is acceptable in order to reduce the variance of the equalized price by unity,

λ is a Lagrangean multiplier used in the calculations,

$N.I.D.$ (μ, σ^2) means "normally and independently distributed with mean μ, and variance σ^2," and

$N(\mu, \sigma^2)$ means, "normally distributed with mean μ and variance σ^2."

This notation allows for $m+1$ weights, $w_0, w_1, \cdots, w_m$, so that m is the number of years over which payment is spread, where we do not consider payment to producers in the year of marketing their product as involving any spreading.

Two identities follow from the above definitions:

$$f_i = (p_i - e_i)q_i \qquad (i = 1, 2, \cdots), \tag{1}$$

and

$$F_i = \sum_{j=0}^{i} f_j \qquad (i = 1, 2, \cdots). \tag{2}$$

Unbiased Equalization Functions

A reasonable requirement for an equalization function is that it should be *unbiased* in the sense that the expected payment into (or out of) the fund in any year should be zero: that is, $E(f_i) = 0$ where f_i is defined as in (1).

The bias of any equalization function will depend on the underlying supply and demand functions which generate the observed price, p_i, and quantity, q_i. A very wide range of supply and demand functions can be specified, each function appropriate to particular conditions, and each leading to its own criteria for unbiasedness of the equalization function.

One of the simplest situations to consider is where the quantity offered for sale is stochastic but independent of current price. Price, however, is dependent on the amount supplied. Stated in terms of linear functions, this situation could be expressed as follows:

Demand function

$$(3) \qquad p_i = \alpha + \beta q_i + \epsilon_i; \qquad E(\epsilon_i) = 0; \qquad E(\epsilon_i^2) = \sigma_d^2;$$

Supply function

$$(4) \qquad q_i = \gamma + \theta_i; \qquad E(\theta_i) = 0; \qquad E(\theta_i^2) = \sigma_s^2.$$

If we allow for correlation but not for auto, or serial, correlation, we can also specify as follows:

Correlation assumptions

$$(5) \quad E(\epsilon_i\theta_i) = \sigma_{sd}; \quad E(\epsilon_i\epsilon_j) = 0; \quad E(\theta_i\theta_j) = 0; \quad E(\epsilon_i\theta_j) = 0\ (i \neq j).$$

The simplest form for the equalization function would be that equalized price is a weighted sum of the current price and prices previously received:

Equalization function

$$(6) \qquad e_i = \sum_{j=0}^{m} p_{i-j} w_j \qquad (i = 1, 2, \cdots).$$

Given the above assumptions, we can state the requirement for an unbiased equalization function:

$$(7) \qquad \sum_{j=0}^{m} w_j = 1 + \frac{(1 - w_0)(\beta\sigma_s^2 + \sigma_{sd})}{\alpha\gamma + \beta\gamma^2}\,.$$

For $i < m$, the equalization function (6) includes terms in p_k where $k \leq 0$. In order to ensure that the first few years of the equalization function are unbiased, we need to select these dummy prices to ensure that $F_m = f_0$. Assuming that the weights $w_i (i = 0, \cdots, m)$ have been selected, we must choose the p_k's to satisfy the equations

$$(7a) \qquad F_1 = F_2 = \cdots = F_m = f_0,$$

and

$$(7b) \qquad p_k = \frac{p_{m-k} - \sum_{j=0}^{k-1} w_j p_{m-k-j}}{w_k} \qquad (k = 0, -1, \cdots, -m).$$

This way of starting the function off has two disadvantages: (*a*) that p_0 to p_{-m} cannot be calculated until p_m is known, and (*b*) that, though the function is guaranteed to be unbiased in the first few years, there is no reduction of variance. Thus, more subjective ways of starting the system off may have more practical appeal.

Alternative supply and demand models might include constant elasticity supply and demand functions, lagged price and quantity relationships, supply dependent on price, less restrictive assumptions about the lagged correlations of the error terms, and some allowance for trend. For these more complicated situations, efficient equalization functions would need to be derived to suit each particular model.

The model represented by equations (3) through (5) may be a reasonable approximation to the real life situation of primary producers where (*a*) price is determined by exports to the world market, and the country produces only a small proportion of total world production, (*b*) the production process takes a number of years, and (*c*) there is no trend in output or prices.

This would be true, for instance, for exports of many livestock products and perennial crops. It would also be true for the exports of annual crops which rely on large capital inputs for irrigation, processing machinery, or the like.

If world demand is insensitive to changes in production from the individual supplier being considered, and if the error terms connecting national supply and world demand are statistically independent, then $\beta = \sigma_{sd} = 0$, and the unbiasedness requirement reduces to

$$(8) \qquad \sum_{j=0}^{m} w_j = 1.$$

In this latter case, an unbiased equalization function can be selected *without knowing* the expected value of market prices or output.

Variance of Equalization Fund and Payments

In addition to wanting the equalization function to be unbiased, we might reasonably want it to minimize some weighted sum of the variance of equalized payments, the variance of farmers' incomes, and the variance of the size of the equalization fund. That is, given equations (3) to (7), we might wish to minimize the Lagrangean function:

(9) $$L = \sigma_e^2 + \phi_1\sigma_y^2 + \phi_2\sigma_F^2 + \lambda\left\{1 + \frac{(1 - w_0)(\beta\sigma_s^2 + \sigma_{sd})}{\alpha\gamma + \beta\gamma^2} - \sum_{j=0}^{m} w_j\right\}.$$

Here,

σ_e^2 is the variance of the equalized payments,
σ_y^2 is the variance of farmers' incomes (from the product),
σ_F^2 is the variance of the equalization fund, and
ϕ_1, ϕ_2 are weights characterizing the relative importance attached to the different types of variance.

The expected value of the equalized price (6) can be seen to be

(10) $$E(e_i) = (\alpha + \beta\gamma) \sum_{j=0}^{m} w_{i-j}$$

and the variance of these equalized payments can then be shown to be

(11) $$\sigma_e^2 = (\sigma_d^2 + 2\beta\sigma_{sd} + \beta^2\sigma_s^2) \sum_{j=0}^{m} w_j^2.$$

Writing equalized grower income as y_i, we have

(12) $$y_i = e_i q_i,$$

from which we can see that the expected value of farmers' equalized income is

(13) $$E(y_i) = (\alpha\gamma + \beta\gamma^2) \sum_{j=0}^{m} w_j + w_0(\beta\sigma_s^2 + \sigma_{sd}).$$

The variance of farmers' equalized income[1] involves some fourth-order terms, such as $w_0 E(\theta_i^4)$, which need not necessarily be expected to be zero.[2]

---

[1] The exact expression for this variance is

$$\begin{aligned}\sigma_y^2 = {} & w_0^2[2\beta\gamma(\alpha + \beta\gamma)\sigma_s^2 + 2(\beta + \gamma)(\alpha + \beta\gamma)\sigma_{sd} - (\beta\sigma_s^2 + \sigma_{sd})^2] \\ & + \sum_{j=0}^{m} w_j^2[\{\beta\gamma^2 + (\alpha + \beta\gamma)^2 + 2\beta^2\gamma\}\sigma_s^2 + \gamma\sigma_d^2 + 2\beta\gamma^2\sigma_{sd}] \\ & + \sum_{j=0}^{m} w_j^2[\beta^2 E(\theta_i^2\theta_{i-j}^2) + E(\theta_i^2\epsilon_{i-j}^2) + 4\beta\gamma E(\theta_{i-j}\theta_i\epsilon_{i-j}) \\ & + 2\gamma E(\epsilon_{i-j}^2\theta_i) + 2(\alpha + \beta\gamma)E(\theta_i^2\epsilon_{i-j}) + \beta E(\theta_i^2\epsilon_{i-j}\theta_{i-j})].\end{aligned}$$

[2] Assuming that $\sum^m_{j=0} w_j$ satisfies (7), and writing $w_0^* = 1 - w_0$, and $w_i^* = -w_i$ $(i = 1, \cdots, m)$, then the variance of the equalization fund can be written as follows:

$$\begin{aligned}\sigma_F^2 = {} & \sum_{i=1}^{k}\sum_{j=0}^{m} w_j^*\{\gamma^2(\alpha^2 + \beta^2\gamma^2 + 2\alpha\beta\gamma) + (\alpha^2 + 2\beta^2\gamma^2 + 2\alpha\beta\gamma)\sigma_s^2 + \gamma^2\sigma_d^2 + 2\gamma^2\beta\sigma_{sd}\} \\ & + w_0 \sum_{i=1}^{k} \{(\beta^2 + 2\beta^2\gamma^2 + 4\alpha\beta\gamma)\sigma_s^2 + (1 + 2\beta\gamma^2 + 4\alpha\gamma)\sigma_{sd}\} \\ & + 2\sum_{i=1}^{k}\sum_{j=0}^{m} w_j^*\{\beta\gamma^2 E(\theta_i\theta_{i-j}^2) + \beta\gamma E(\theta_i\theta_{i-j}\epsilon_{i-j}) + \beta\gamma E(\theta_i\theta_{i-j}\epsilon_{i-j}) \\ & + \beta E(\theta_i^2\theta_{i-j}\epsilon_{i-j}) + \gamma E(\theta_i\theta_{i-j}^2)\}.\end{aligned}$$

In the numerical example considered below, it is assumed that output is constant.[3] In this case, the variance of income is proportional to the variance of price, and the rather complex expression for σ_y^2 is not relevant.

The value of the equalization fund at the end of the ith year can be written as in (2). The expected value of the fund is

$$(14)\quad E(F_k) = E\left\{f_0 + \sum_{i=1}^{k} (\gamma + \theta_i)(\alpha + \beta\gamma + \beta\theta_i + \epsilon_i) - \sum_{j=0}^{m} w_j(\alpha + \beta\gamma + \beta\theta_{i-j} + \epsilon_{i-j})\right\}$$

or

$$(15)\quad E(F_k) = f_0 + \sum_{i=1}^{k} \left\{\alpha\gamma + \beta\gamma^2 + \beta\sigma_s^2 + \sigma_{sd} - \frac{\sum_{j=0}^{m} w_j(\alpha\gamma + \beta\gamma^2) - w_0(\beta\sigma_s^2 + \sigma_{sd})}{\sum_{j=0}^{m} w_j}\right\}.$$

Provided that (7) and (7b) hold, this reduces to $E(f_k) = f_0$. The variance formula for the equalization fund is also rather complex, involving terms in $w_0E(\theta_1^4)$.

To obtain efficient weights, we need only to differentiate the Lagrangean function (9) partially with respect to the $w_i(i=0, \cdots, m)$ and set the partial derivatives equal to zero. Since this procedure locates the stationary point for a weighted sum of variances, the second order conditions for a minimum will be satisfied.

Given the numerical values of the parameters involved in (9) and the variances σ_e^2, σ_y^2, and σ_f^2, we would find the differentiation relatively straightforward. In the light of the other models of the underlying demand and supply situation which could be formulated and the absence of an empirical example of the general model, equations (3) through (6), we do not think it worthwhile to derive a general formula for the partial derivatives of (9). There is, however, one simple case where general formulas may be of interest, especially since to some extent they contradict "common sense."

[3] Equivalent, and apparently less restrictive, assumptions would be the following: (a) supply is nonstochastic and grows at a constant rate in line with the rate of interest, $q_i = (1+r)^i\gamma$ where r is the rate of interest expressed as a decimal; and (b) the demand function is stochastic but "moves up" at the same constant rate:

$$p_i = (1 + r)^i\alpha + \beta q_i + \epsilon_i;\ E(\epsilon_i) = 0;\ E(\epsilon_i^2) = (1 + r)^{2i}\sigma_d^2.$$

These two assumptions result in a price per unit of

$$\frac{p_i}{q_i} = (\alpha + \beta) + \frac{\epsilon_i}{(1 + r)^i};\quad E\,\frac{\epsilon_i}{(1 + r)^i} = 0;\quad E\,\frac{\epsilon_i^2}{(1 + r)^{2i}} = \sigma_d^2.$$

The simple case for which efficient weight will be derived is where market price depends on export price and where the county's production is only a small fraction of world consumption—that is, where β in (3) can be taken equal to zero—and where output fluctuations are small—that is, where σ_s^2 in (4) can be taken equal to zero.

In this case, many of the terms in σ_e^2, σ_y^2, and σ_F^2 disappear, since output is assumed constant, the variance of incomes, σ_y^2, is proportional to the variance of equalized prices, σ_e^2. Thus, the Lagrangean expression (9) can be replaced by a simpler objective function which is minimized:

$$L = \sigma_e^2 + \phi\sigma_F^2 + \lambda\left(1 - \sum_{j=0}^{m} w_j\right). \tag{16}$$

The right-hand term reflects the unbiasedness requirement (8), which replaces (7), given the restrictions assumed for this simple case.

Efficient Weights for a Simple Problem

A quick review of the simple problem for which an efficient equalization function is to be derived may be useful.

An *efficient equalization function* is an equalization function which accepts a stream of market prices, $p_1, p_2, \cdots$, and transforms them into a series of equalized prices, $e_1, e_2, \cdots$, such that the expected value of $(p_i - e_i)$ is zero, and for any given variance of the equalization fund, σ_F^2, the variance of the equalized prices σ_e^2 (and, hence, variance of equalized incomes σ_y^2) is a minimum.

In this case, the unbiasedness requirement reduces to

$$\sum_{j=0}^{m} w_j = 1; \tag{8}$$

and the variance of equalized prices reduces to

$$\sigma_e^2 = \sigma^2 \sum_{j=0}^{m} w_j^2. \tag{17}$$

Here, the subscript d has been omitted from σ_d^2 on the right of (17), since σ_s^2 is assumed to be zero.

The relationship of the equalized price and equalization fund to actual prices received is easily seen by considering the first few years of an equalization scheme with $m=2$, and $f_0=0$.

Given $p_i(i=-1, 0, 1, 2, \cdots)$, we have, from (6),

$$e_1 = p_1w_0 + p_0w_1 + p_{-1}w_2, \tag{18}$$

$$e_2 = p_2w_0 + p_1w_1 + p_0w_2, \tag{19}$$

and

$$e_i = p_i w_0 + p_{i-1} w_1 + p_{i-2} w_2 \qquad (i > 2), \tag{20}$$

where p_0 and p_{-1} are fixed constants used to "start the scheme off."

The behavior of the equalization fund—later expressed in (27)—is as follows:

$$F_1 = (1 - w_0)p_1 - w_1 p_0 - w_2 p_{-1}, \tag{21}$$

$$F_2 = (1 - w_0)p_2 + (1 - w_0 - w_1)p_1 - (w_1 + w_2)p_0 - w_2 p_{-1}, \tag{22}$$

and

$$\begin{aligned} F_3 = (1 - w_0)p_3 &+ (1 - w_0 - w_1)p_2 + (1 - w_0 - w_1 - w_2)p_1 \\ &- (w_1 + w_2)p_0 - w_2 p_{-1}, \end{aligned} \tag{23}$$

or, in the light of (8),

$$\begin{aligned} F_i = (1 - w_0)p_i &+ (1 - w_0 - w_1)p_{i-1} \\ &- (w_1 + w_2)p_0 - w_2 p_{-1} \qquad (i > 2). \end{aligned} \tag{24}$$

The expected value of F_i can be seen to be

$$\begin{aligned} E(F_i) = (1 - w_0)E(p_i) &+ (1 - w_0 - w_1)E(p_{i-1}) \\ &- (w_1 + w_2)p_0 - w_2 p_{-1} \qquad (i > 2), \end{aligned} \tag{25}$$

or

$$\begin{aligned} E(F_i) = \alpha\{(1 - w_0) &+ (1 - w_0 - w_1)\} \\ &- (w_1 + w_2)p_0 - w_2 p_{-1} \qquad (i > 2), \end{aligned} \tag{26}$$

from which it can be seen that if $p_0 = p_{-1} = \alpha$, then the expected value of the equalization fund would be zero. Similarly, (26) or (28) shows that any periods of exceptionally high or low prices will eventually be reflected in the equalized price, *and hence have no permanent effect on the value of the equalization fund.* By contrast, the values of p_0, p_{-1}, which are used to start the equalization scheme off, have a permanent effect on the expected value of the equalization fund.

Given the equalization function (6), and zero as the initial level of the fund, we find that the value of the equalization fund at the end of the ith year is

$$F_i = \sum_{j=0}^{m} \left(1 - \sum_{k=0}^{j} w_k\right) p_{i-j} - \sum_{j=1}^{m} \sum_{k=j}^{m} w_k p_{1-j} \qquad (i = 1, 2, \cdots). \tag{27}$$

This ignores administrative cost and assumes that the expected value of interest payments is zero, an assumption which implies that the periods when the fund is in deficit and those when it is in surplus will occur in random order.

This function has mean

$$\mu_F = \alpha \sum_{j=1}^{m} \left(1 - \sum_{k=0}^{j} w_k\right) - \sum_{j=1}^{m} \sum_{k=j}^{m} w_k p_{1-j} \tag{28}$$

and variance

$$\sigma_F{}^2 = \sigma^2 \sum_{j=0}^{m} \left(1 - \sum_{k=0}^{j} w_k\right)^2. \tag{29}$$

As stated above, we can consider the problem of selecting an optimum equalization function. Find weights $w_i (i=0, 1, \cdots, m)$ such that

$$z = \sigma_e{}^2 + \phi\sigma_F{}^2 \tag{30}$$

is minimized, subject to

$$\sum_{i=0}^{m} w_i = 1, \tag{8}$$

where ϕ is constant, determining the relative importance attached to variance of the equalized payments and of the equalization fund.

Writing (30) in full, and adding a Lagrangean multiplier to take account of (8), we have the Lagrangean problem of finding weights $w_i (i=0, 1, \cdots, m)$ and Lagrangean multiplier λ such that we minimize

$$z = \sigma^2 \sum_{j=0}^{m} w_j{}^2 + \phi\sigma^2 \sum_{j=0}^{m} \left(1 - \sum_{k=0}^{j} w_k\right)^2 + \lambda \left(1 - \sum_{j=0}^{m} w_j\right) \tag{31}$$

or

$$z^* = \sum_{j=0}^{m} w_j{}^2 + \phi \sum_{j=0}^{m} \left(1 - \sum_{k=0}^{j} w_k\right)^2 + \lambda^* \left(1 - \sum_{j=0}^{m} w_j\right), \tag{32}$$

where

$$\lambda^* = \frac{\lambda}{\sigma^2} \quad \text{and} \quad z^* = \frac{z}{\sigma^2}. \tag{33}$$

Setting the partial derivatives of (32) equal to zero gives

$$\frac{\partial z^*}{\partial \lambda^*} = 1 - \sum_{j=0}^{m} w_j = 0, \tag{34}$$

$$\frac{1\partial z^*}{2\partial w_m} = w_m - \phi \left(1 - \sum_{j=0}^{m} w_j\right) - \frac{\lambda^*}{2} = 0, \tag{35}$$

and

$$\frac{1\partial z^*}{2\partial w_i} = w_i - \phi \sum_{k=i}^{m} \left(1 - \sum_{j=0}^{k} w_j\right) - \frac{\lambda^*}{2} = 0 \quad (i = 0, 1, \cdots, m-1). \tag{36}$$

Since z^* is the sum of two variances, the stationary point must correspond to the minimum value of z^*.[4]

Given (34), we see that (35) implies

$$\lambda^* = 2w_m. \tag{37}$$

And, again using (34), we can rewrite equation (36) as

$$w_i = w_m + \phi \sum_{k=i}^{m} \sum_{j=k+1}^{m} w_j \qquad (i = 0, 1, \cdots, m-1) \tag{38}$$

or

$$w_i = w_m + \phi \left\{ \sum_{j=i+1}^{m} (j-1) w_j \right\} \qquad (i = 0, 1, \cdots, m-1). \tag{39}$$

Writing the weights $w_i (i=0, 1, \cdots, m)$ as fractions, with numerators n_i and denominator d_m, we have

$$w_i = \frac{n_i}{d_m} \qquad (i = 0, 1, \cdots, m) \tag{40}$$

or

$$n_i = w_i d_m \qquad (i = 0, 1, \cdots, m). \tag{41}$$

The numerators n_i can be obtained from (34), (39), and (41):

$$\begin{aligned}
n_m &= w_m d_m, \\
n_{m-1} &= (w_m + \phi w_m) d_m = (1 + \phi) w_m d_m, \\
n_{m-2} &= (1 + 3\phi + \phi^2) w_m d_m, \\
n_{m-3} &= (1 + 6\phi + 5\phi^2 + \phi^3) w_m d_m, \\
n_{m-4} &= (1 + 10\phi + 15\phi^2 + 7\phi^3 + \phi^4) w_m d_m,
\end{aligned}$$

and so on sequentially.

To satisfy (34), the denominator is

$$d_m = \sum_{i=0}^{m} n_i. \tag{42}$$

Efficient numerators and denominators are given for $m=0, \cdots, 5$ in Table 1.

The relative variance of the equalized payout, and of the equalization fund, are given in Table 2. In this table, the variance of the equalized price

[4] Direct proof that the matrix of second-order derivatives would be positive definite looks to be a tedious exercise.

Table 1. Efficient equalization weights for $m = 0, \cdots, 5$, given normally and independently distributed prices

m	Numerator						Denominator
	n_0	n_1	n_2	n_3	n_4	n_5	
0	1						1
1	$1+\phi$	1					$2+\phi$
2	$1+3\phi+\phi^2$	$1+\phi$	1				$3+4\phi+\phi^2$
3	$1+6\phi$ $+5\phi^2+\phi^3$	$1+3\phi+\phi^2$	$1+\phi$	1			$4+10\phi+6\phi^2$ $+\phi^3$
4	$1+10\phi+15\phi^2$ $+7\phi^3+\phi^4$	$1+6\phi$ $+5\phi^2+\phi^4$	$1+3\phi$ $+\phi^2$	$1+\phi$	1		$5+20\phi+21\phi^2$ $+8\phi^3+\phi^4$
5	$1+15\phi+35\phi^2$ $+28\phi^3+9\phi^4$ $+\phi^5$	$1+10\phi$ $+15\phi^2$ $7\phi^3+\phi^4$	$1+6\phi$ $+5\phi^2+\phi^3$	$1+3\phi$ $+\phi^2$	$1+\phi$	1	$6+35\phi+56\phi^2$ $+36\phi^3+10\phi^4$ $+\phi^5$

Table 2. Efficient variance combinations for $m = 0, \cdots, 9$, and a range of Φ

m		Relative importance of equalization fund (ϕ)									
		0	0.1	0.2	0.4	0.6	1.0	1.25	1.50	2.0	4.0
1	$\tilde{\sigma}_e^2$	0.500	0.501	0.504	0.514	0.527	0.556	0.574	0.592	0.625	0.722
	$\tilde{\sigma}_f^2$	0.250	0.227	0.207	0.174	0.148	0.111	0.095	0.082	0.063	0.028
2	$\tilde{\sigma}_e^2$	0.333	0.338	0.348	0.376	0.408	0.469	0.502	0.532	0.582	0.708
	$\tilde{\sigma}_f^2$	0.556	0.465	0.396	0.298	0.234	0.156	0.126	0.105	0.076	0.030
3	$\tilde{\sigma}_e^2$	0.250	0.260	0.280	0.328	0.374	0.451	0.490	0.523		
	$\tilde{\sigma}_f^2$	0.875	0.665	0.527	0.361	0.267	0.168	0.133	0.109		
4	$\tilde{\sigma}_e^2$	0.200	0.217	0.248	0.311	0.365	0.448				
	$\tilde{\sigma}_f^2$	1.200	0.819	0.608	0.388	0.278	0.170				
5	$\tilde{\sigma}_e^2$	0.167	0.192	0.232	0.305						
	$\tilde{\sigma}_f^2$	1.528	0.929	0.653	0.399						
6	$\tilde{\sigma}_e^2$	0.143	0.177	0.225	0.303						
	$\tilde{\sigma}_f^2$	1.857	1.006	0.677	0.403						
7	$\tilde{\sigma}_e^2$	0.125	0.169	0.221							
	$\tilde{\sigma}_f^2$	2.188	1.056	0.689							
8	$\tilde{\sigma}_e^2$	0.111	0.164	0.220							
	$\tilde{\sigma}_f^2$	2.519	1.089	0.695							
9	$\tilde{\sigma}_e^2$	0.100	0.160	0.219	0.302	0.361	0.447	0.488	0.522	0.577	0.707
	$\tilde{\sigma}_f^2$	2.850	1.109	0.698	0.404	0.283	0.171	0.134	0.109	0.077	0.030

series is expressed relative to the variance of the initial price series and the variance of the equalization fund is expressed relative to total output. That is, in the top left-hand corner of Table 2, it is stated that with $m=1$, $\phi=0$, the resulting variance of the equalized payouts is only half as great as the variance of the initial stream of prices. The variance of the equalization fund per unit of commodity protected is only a quarter of the variance of the initial stream of prices.

As an example of the calculations used to derive Table 2, consider the efficient equalization function for $m=2$ and $\phi=0.4$.

From Table 1, we can see that the successive numerators should be

$$\begin{aligned} n_0 &= 1 + (3 \times 0.4) + (0.4 \times 0.4) &&= 2.36 \\ n_1 &= 1 + 0.4 &&= 1.40 \\ n_2 &= 1 &&= 1.00 \end{aligned}$$

and the denominator should be

$$d_3 = n_0 + n_1 + n_2 = 4.76.$$

Thus, the weights for the efficient equalization functions are

$$w_0 = 0.49580; \qquad w_1 = 0.29412; \qquad w_2 = 0.21008.$$

Using equation (17), we see that the variance of the equalized payouts, σ_e^2, will be

$$\sigma_e^2 = \sigma^2(0.49580^2 + 0.29412^2 - 0.21008^2) = 0.37646\sigma^2,$$

or the relative variance of the equalized prices will be

$$\tilde{\sigma}_e^2 = 0.376.$$

The variance of the equalization fund is given in (29) as

$$\sigma_F^2 = \sigma^2\{(1 - 0.49580)^2 + (1 - 0.49580 - 0.29412)^2 + (1 - 0.49580 - 0.29412 - 0.21008)^2\}$$

or

$$\sigma_F^2 = \sigma^2(0.50420^2 + 0.21008^2) = 0.29835\sigma^2,$$

or the relative variance (per pound of wool) of the equalization fund is

$$\tilde{\sigma}_F^2 = 0.298.$$

These two numbers, $\tilde{\sigma}_e^2=0.376$ and $\tilde{\sigma}_F^2=0.298$, appear in the $m=2$ row and $\phi=0.4$ column of Table 2.

An Application Involving Wool

New Zealand produces about 630 million pounds of wool per year,[5] and

[5] Six hundred and twenty-three pounds greasy wool in 1964-65 [2, p. 9].

this is sold either privately or at auction. In either case, the price received for wool is dominated by the latest auction price, which may vary from week to week. The average annual price for wool received over the last 20 years is given in Table 3. Price is expressed in cents per pound. Over the last ten years the average price has been 37.33 cents, with variance 27.08 cents.

Table 3. Average price of New Zealand wool, 1945-46 to 1964-65

Season	Cents per pound
1945-46	12.08
1946-47	14.86
1947-48	20.93
1948-49	21.51
1949-50	31.65
1950-51	73.20
1951-52	33.49
1952-53	38.49
1953-54	41.87
1954-55	41.39
1955-56	38.49
1956-57	45.63
1957-58	34.30
1958-59	30.06
1959-60	37.21
1960-61	33.62
1961-62	32.65
1962-63	35.70
1963-64	45.89
1964-65	35.08

The New Zealand Wool Commission has a capital sum of approximately $60 million originating from bulk-purchase arrangements for wool made during World War II. If we assume that policy makers would be willing to use these funds to establish an equalized wool price along the lines outlined earlier, then, given certain assumptions, we can use the above arguments to consider the degree of reduction in price variance to growers which might reasonably be achieved. Important assumptions would be the following:

(*a*) That the national wool clip increases at about 5 percent per annum, so that interest on the $60 million average equalization-fund holding will just allow the increased clip to be protected at the same level as the present clip.

(*b*) That there is no trend in wool prices.

(*c*) That the gain in interest when the fund is above the initial $60 million will offset the reduction in interest when the fund is below the initial $60 million.

(*d*) That policy makers are willing to accept the probability that one year in 40 the fund would actually be in debit.

(*e*) That successive annual wool prices are normally and independently distributed—that is, ε_i is NID $(0, \sigma^2)$.[6]

(*f*) That the variance of quantity produced is small.[7]

Given these assumptions, we can make the following observations:

1. Assumption *e* above implies that the prices p_j are normally distributed. Since the ϵ_i and F_i are linear combinations of the p_i, they too will be normally distributed with the means and variances calculated earlier.

2. Since the national wool clip is 630 million pounds, and the initial level of the fund is taken to be \$60 million, the equalization fund will be in debit if the fund is "out of pocket" 6000/630 cents per pound, or 9.52 cents per pound. That is, the *total* payout per pound can exceed *total* receipts by up to 9.52 cents per pound without the fund itself having to go into debit.

3. The probability that the fund will be in credit in at least 39 of every 40 years may be taken as corresponding to the condition that

$$1.96\sigma_{fc} \leq 9.52, \tag{43}$$

where σ_{fc} is the standard deviation of the equalization fund expressed in cents. This condition means that

$$\sigma_{fc} \leq 4.86 \tag{44}$$

and

$$\sigma_{fc}^2 \leq 23.62. \tag{45}$$

4. The symbol $\bar{\sigma}_f^2$ was used in Table 2 to refer to the variance (per pound of wool) of the equalization fund *relative* to the variance of the initial price series. That is,

$$\bar{\sigma}_f^2 = \frac{\sigma_{fc}}{\sigma^2}, \tag{46}$$

where σ^2, the variance of annual wool prices over the last ten years, has already been given as $\sigma^2 = 27.08$ cents. Thus, the critical value for the equalization fund's being in credit in 39 of 40 years amounts to

$$\bar{\sigma}_f^2 = \frac{\sigma_{fc}}{\sigma^2} \leq \frac{23.62}{27.08} = 0.872. \tag{47}$$

If we assume that successive wool prices are independent, then Table 2 suggests that any of the parameter pairs outside the box in the bottom left corner of the table would be acceptable. A series of possible parameter

[6] The autocorrelation coefficient for the last ten prices given in Table 4 is 0.021.

[7] For an analysis suggesting that, in Australia at least, variations in supply are responsible for *at most* 15 percent of total wool income variance, see Powell [3, p. 86].

Table 4. Possible equalization functions for New Zealand wool[a]

m	2	3	4	3	4	5
ϕ	0	0.1	0.1	0.2	0.2	0.2
w_0	0.3333	0.3262	0.2988	0.3854	0.3692	0.3627
w_1	0.3333	0.2588	0.2288	0.2624	0.2430	0.2353
w_2	0.3333	0.2173	0.1815	0.1920	0.1655	0.1549
w_3		0.1975	0.1524	0.1600	0.1211	0.1055
w_4			0.1385		0.1009	0.0771
w_5						0.0643
$\bar{\sigma}_e^2$	0.333	0.260	0.217	0.280	0.248	0.232
$\bar{\sigma}_f^2$	0.556	0.665	0.819	0.527	0.608	0.653

[a] $\bar{\sigma}_e^2$ and $\bar{\sigma}_f^2$ are computed on the assumption that the price series is normally and independently distributed.

combinations has been listed in Table 4, together with the appropriate weights.

The equalized payout and the level of the equalization fund for New Zealand wool prices over the last ten years, using each of these functions, and the assumption that output was constant at $630m$ per pound, are given in Table 5. The top section of Table 5 assumes that wool prices from the immediately preceding years were used to start the system off. The bottom half of the table assumes that $p_0=p_{-1}= \cdots =p_{-10}=36.863$ cents, the average wool price for the ten years referred to in Table 5.

Since successive values of the fund are not independent, if it *does* go into deficit, the conditional probability of deficit in the next year will be more than 0.025.

Conclusions

Possibly the most interesting rule of thumb emerging from the above study is that if we want to avoid excessive fluctuations in the equalization fund, then most of the market price should be paid out in the equalized payment within the first year or two of receipt. Functions of this sort will also avoid any danger of a major divorce between market price and equalized payout in the event of a secular rise or decline in market prices.[8]

The "instinctive" suggestion of a moving average with equal weights is appropriate only if fluctuations in the equalization fund are of no interest.

[8] Bauer and Paish [1] discuss fully the dangers of this sort of divorce between market price and equalized payout.

Table 5. Performance of alternative equalization functions applied to New Zealand wool prices (1955-56 to 1964-65)[a]

Year	Price	Equalized payout												Base prices
		Pay	Fund	Pay	Fund	Pay	Fund	Pay	Fund	Pay	Fund	Pay	Fund	
1955-56	38.49	40.6	46.8	40.0	50.7	39.1	56.3	39.9	51.2	39.2	55.3	41.5	40.8	PREVIOUS
1956-57	45.63	41.8	70.8	42.1	72.9	41.7	81.3	42.3	71.9	42.0	78.1	41.6	66.5	
1957-58	34.30	39.5	38.2	39.5	39.9	39.8	46.8	39.2	41.0	39.4	46.3	39.2	35.6	
1958-59	30.06	36.7	−3.4	36.2	1.2	36.7	4.9	35.5	6.7	35.8	10.0	36.0	−1.8	
1959-60	37.21	33.9	17.8	36.4	6.4	36.5	9.3	36.1	13.6	31.1	16.8	36.3	3.8	
1960-61	33.62	33.6	17.7	33.9	4.6	35.6	−2.9	34.0	11.4	35.2	6.9	35.2	−6.3	
1961-62	32.65	34.5	6.1	33.4	0.1	33.5	−8.5	33.4	6.9	33.5	1.6	34.3	−16.4	
1962-63	35.70	34.0	16.9	34.7	6.1	34.1	1.7	34.7	13.0	34.2	11.0	34.3	−7.6	
1963-64	45.89	38.1	66.2	37.9	56.1	38.1	50.9	38.7	58.3	38.8	55.4	38.5	39.3	
1964-65	35.08	38.9	42.2	37.5	40.7	37.1	38.2	37.6	42.1	37.4	41.0	37.5	24.2	
m		2		3		4		3		4		5		
ϕ		0		0.1		0.1		0.2		0.2		0.2		
1955-56	38.49	37.4	66.9	37.4	67.0	37.3	67.2	37.5	66.3	37.5	66.5	37.4	66.6	AVERAGE
1956-57	45.63	40.3	100.3	40.1	101.6	39.9	103.6	40.7	97.6	40.5	99.0	40.4	99.4	
1957-58	34.30	39.5	67.7	38.6	74.2	38.4	77.8	38.5	71.3	38.3	73.7	38.2	74.6	
1958-59	30.06	36.7	26.1	36.2	35.5	36.1	39.8	35.5	37.0	35.4	40.3	35.3	41.5	
1959-60	37.21	33.9	47.3	36.4	70.7	36.5	44.2	36.1	43.9	36.1	47.1	36.0	48.9	
1960-61	33.62	33.6	47.2	33.9	39.0	35.6	32.0	34.0	41.6	35.2	37.2	35.2	38.8	
1961-62	32.65	34.5	35.7	33.4	34.4	33.5	26.4	33.4	37.2	33.5	32.0	34.3	28.6	
1962-63	35.70	34.0	46.5	34.7	40.4	34.1	36.7	34.7	43.3	34.2	41.3	34.3	37.5	
1963-64	45.89	38.1	95.7	37.9	90.4	38.1	85.9	38.7	88.5	38.8	85.7	38.5	84.4	
1964-65	35.08	38.9	71.7	37.5	75.0	37.1	73.2	37.6	72.4	37.4	71.3	37.5	69.3	

[a] Levels of the fund are in million dollars, wool prices in cents per pound. Wool production is assumed constant at 630 million pounds.

or, grouping the expressions in terms of the weights $w_j (j=0, \cdots, m)$,

$$\text{(A8)} \quad V^* = \lambda + \phi[1 + m(1+\theta)] - w_0[\lambda + 2\phi\{1 + m(1+\theta)\}]$$
$$- \sum_{j=1}^{m} w_j(\lambda + \phi\{2(m-j+1) + \theta(2[m-j]+1)\}]$$
$$+ \sum_{j=0}^{m} w_j^2[1 + \phi\{1 + (m-j)(1+\theta)\}]$$
$$+ \sum_{j=1}^{m} w_j w_{j-1}[\theta + \phi\{2(m-j+1) + \theta(2[m-j]+1)\}]$$
$$+ \sum_{i=0}^{m-2} \sum_{j=i+2}^{m} w_i w_j[\phi\{2(m-j+1) + \theta(2[m-j]+1)\}].$$

Taking the partial derivatives of this expression, we obtain

$$\text{(A9)} \qquad \frac{\partial V^*}{\partial \lambda} = 1 - \sum_{j=0}^{m} w_j$$

and

$$\text{(A10)} \quad \frac{\partial V^*}{\partial w_0} = -\lambda + 2\phi\{1 + m(1+\theta)\} + 2w_0[1 + \phi\{1 + m(1+\theta)\}]$$
$$+ w_1[\theta + \phi(2m + \theta(2m-1))]$$
$$+ \sum_{j=2}^{m} w_j[\phi\{2(m-j+1) + \theta(2[m-j]+1)\}]$$

and

$$\text{(A11)} \quad \frac{\partial V^*}{\partial w_1} = -\lambda + \phi\{2m + \theta(2m-1)\} + w_0[\theta + \phi\{2m + \theta(2m-1)\}]$$
$$+ w_1[2\{1 + \phi m + \phi\theta(m-1)\}]$$
$$+ w_2[\theta + \phi\{2(m-1) + \theta(2m-3)\}]$$
$$+ \sum_{j=3}^{m} w_j[\phi\{2(m-j+1) + \theta(2[m-j]+1)\}]$$

and

$$\text{(A12)}\quad \frac{\partial V^*}{\partial w_i} = -\lambda + \phi[2\{m-i+1\} + \theta\{2(m-i)+1\}]$$
$$+ \sum_{k=0}^{i-2} w_k[\phi\{2(m-i+1)+\theta(2[m-i]+1)\}]$$
$$+ w_{i-1}[\theta + \phi\{2(m-i+1)+\theta(2[m-i]+1)\}]$$
$$+ w_i[2\{1+\phi(1+[m-i][1+\theta])\}]$$
$$+ w_{i+1}[\theta + \phi\{2(m-i)+\theta(2[m-i]-1)\}]$$
$$+ \sum_{k=i+2}^{m} w_k[\phi\{2(m-k+1)+\theta(2[m-k]+1)\}] \quad (i > 2).$$

Setting these partial derivatives equal to zero gives a system of $(m+2)$ equations in $(m+2)$ unknowns, without any obvious sequential pattern in the solutions such as was revealed in Table 1.

Values of the variances of σ_ϵ^2 and σ_f^2 for a range of values of θ, ϕ, and m are given in Table A1.

Table A1. Efficient variance combinations for selected combinations of m, θ, and ϕ

Autocorrelation θ		Relative importance of equalization fund (ϕ)							
		0	0.1	0.2	0.4	0.8	1.0	1.5	2.0
−0.2	m	9	9	8	6	5	4	3	3
	$\bar{\sigma}_\epsilon^2$	0.082	0.131	0.181	0.254	0.353	0.391	0.466	0.522
	$\bar{\sigma}_f^2$	2.390	1.004	0.653	0.396	0.221	0.178	0.117	0.084
0	m	9	9	8	6	4	4	4	3
	$\bar{\sigma}_\epsilon^2$	0.100	0.160	0.220	0.303	0.410	0.448	0.522	0.578
	$\bar{\sigma}_f^2$	2.850	1.109	0.695	0.403	0.213	0.170	0.109	0.077
0.2	m	9	9	8	6	5	4	4	3
	$\bar{\sigma}_\epsilon^2$	0.117	0.190	0.257	0.349	0.462	0.501	0.576	0.629
	$\bar{\sigma}_f^2$	3.304	1.207	0.732	0.407	0.207	0.162	0.101	0.070
0.4	m	9	9	8	6	5	4	3	3
	$\bar{\sigma}_\epsilon^2$	0.135	0.218	0.294	0.394	0.512	0.553	0.627	0.678
	$\bar{\sigma}_f^2$	3.755	1.297	0.764	0.409	0.199	0.153	0.093	0.063
0.6	m	9	9	8	6	5	4	3	3
	$\bar{\sigma}_\epsilon^2$	0.152	0.246	0.330	0.437	0.560	0.600	0.673	0.722
	$\bar{\sigma}_f^2$	4.201	1.378	0.790	0.409	0.190	0.145	0.085	0.057
0.8	m	9	9	8	6	4	4	3	3
	$\bar{\sigma}_\epsilon^2$	0.169	0.274	0.365	0.478	0.603	0.643	0.714	0.759
	$\bar{\sigma}_f^2$	4.640	1.445	0.806	0.403	0.179	0.135	0.077	0.051

References

[1] Bauer, P. T., and F. W. Paish, "The Reduction of Fluctuations in the Incomes of Primary Producers," *Econ. J.* 62:750–780, Dec. 1952.

[2] New Zealand Wool Commission, *Statistical Analysis of New Zealand Wool Production and Disposal, 1964/65 Season,* Wellington, 1965.

[3] Powell, Alan, "Production and Income Uncertainty in the Wool Industry: An Aggregative Approach," *Australian J. Agr. Econ.* 4:86–96, 1960.

Linear and Dynamic Programming in Markov Chains*

YOAV KISLEV AND AMOTZ AMIAD

Some essential elements of the Markov chain theory are reviewed, along with programming of economic models which incorporate Markovian matrices and whose objective function is the maximization of the present value of an infinite stream of income. The linear programming solution to these models is presented and compared to the dynamic programming solution. Several properties of the solution are analyzed and it is shown that the elements of the simplex tableau contain information relevant to the understanding of the programmed system. It is also shown that the model can be extended to cover, among other elements, multiprocess enterprises and the realistic cases of programming in the face of probable deterioration of the productive capacity of the system or its total destruction.

RECENTLY there has been growing interest in programming of economic processes which can be formulated as Markov chain models. One of the pioneering works in this field is Howard's *Dynamic Programming and Markov Processes* [6], which paved the way for a series of interesting applications. Programming techniques applied to these problems had originally been the dynamic, and more recently, the linear programming approach. Practically, a computer program to execute the dynamic programming calculation is simpler to prepare than one for the linear programming procedure. On the other hand, linear programming routines are readily available and allow great flexibility, as in parametric programming and sensitivity analysis. These features can be introduced into dynamic programming routines, although at an increasing cost. In this article we will show the lines of similarity between the two techniques and investigate some possible extensions and applications.

A finite Markov chain is a statistical model useful in describing various economic phenomena.[1] In this model, we envisage a process which is in a certain *state* i, where $i=1, 2, \cdots, n$ (n finite), in a particular *period* or *stage*, and is transformed in the next period to a state j ($j=i$ is permissible). The chain is described by an n-order *transition*, or *Markov* matrix, whose elements p_{ij} are the probabilities that the process will go from state i to state j. These probabilities are independent of the past history of the process.

* We are indebted to Hanna Lifson, who read previous versions of this article and helped to clarify many of its points. The article also benefited from discussions with Amnon Amir, Yakir Plessner, and the late Yoseph Levi, and from comments by the *Journal*'s readers. The work for the article was financed, in part, by a grant from the United States Department of Agriculture under P. L. 480.

[1] For a rigorous and complete treatment of Markov chains see Kemeny and Snell [8].

YOAV KISLEV *is a lecturer in the Department of Agricultural Economics, The Hebrew University, Rehovot, Israel.* AMOTZ AMIAD *is a graduate student in the School of Business Administration, The University of California, Berkeley.*

For example, let us consider a field whose state is defined by the level of humidity of the soil (measured in discrete units). The field may be transformed from one state to another with certain probabilities, depending on crop and weather conditions [1]. Additional illustrations might be a system of pieces of equipment whose failures are a stochastic process [2], or a warehouse where the state is given by the level of inventory [3, 4, 7].

In economic processes, with every state is associated a reward—or cost—for example, yield of the field, repair of machine, profits from sales of items out of inventory. The interesting cases are those in which the transition probabilities can be affected by *action*. A *policy* will then be the rule which dictates an action to be taken in every state. An *optimal* policy will be the policy under which total expected income from the process is maximized. In this framework, programming is the choice of an optimal policy from a given set of alternatives. The choice can be made efficiently by either dynamic or linear programming methods. We will investigate the relations between the two methods and interpret the results of the linear programming calculations. We hope to show not only that linear programming is applicable in this context, as has already been shown [3, 4, 7, 9], but also that its interpretation throws light on the "anatomy" of the system and clarifies understanding of its properties.

In order to simplify the discussion, we will make several assumptions to be relaxed later in the article. First, we assume regular Markov chains, that is, any state is probable far enough in the future. Also we explicitly assume that the transition matrices are not decomposable, that is, that the process cannot be split into two or more isolated chains. We further assume that a series of processes has a unique maximum present value. The discussion is limited to processes of indefinite duration—that is, an infinite economic horizon is assumed.

Income Streams

We start the discussion by noting the mathematical equivalence of three analogous income streams[2] and naming these parallel cases for future reference. As usual, an income stream is defined by its annuity—a_t in period t.

The discounting case

Assume that a process yielding income lasts forever and that $a_t = a_0$ for all t. Let r be the appropriate rate of interest and $\alpha = 1/(1+r)$ be the discounting factor. Then the worth of the source of income—its present value—is

$$z_\alpha = \sum_{t=0}^{\infty} \alpha^t a_0 = a_0/(1-\alpha), \tag{1}$$

since $0 < \alpha < 1$.

[2] In the present context, the analogy was first introduced by D'Epenoux [4].

The deterioration case

Assume now that income from the source is not constant, but deteriorates at the rate β, where $\beta = a_{t+1}/a_t$ and $0<\beta<1$ (radioactive decay). Then the present *not discounted* value of the source of income is

$$z_\beta = \sum_{t=0}^{\infty} a_t = \sum_{t=0}^{\infty} \beta^t a_0 = a_0/(1-\beta). \tag{2}$$

The breakdown case

In this third case, consider a constant annuity, a_0, as long as the source of income exists. There is, however, a constant probability $1-\gamma$, at every period t, that the source will be destroyed before the coming of the next period. Hence, γ is the probability of survival. Here expected worth of the income stream (not discounted) is

$$z_\gamma = \sum_{t=0}^{\infty} \gamma^t a_0 = a_0/(1-\gamma). \tag{3}$$

These three cases are mathematically equivalent. Of course, they could be consolidated into one general case which would constitute a mixture of the three. In the course of our discussion, we shall make use of the analogy of the separate cases, as well as of the mixed case.

It will also be useful if we note that the previous equations can be rewritten in a slightly different form. Instead of (1), for example, write the recurrence relation

$$\begin{aligned} z_\alpha &= a_0 + \alpha \sum_{t=0}^{\infty} \alpha^t a_0 \\ &= a_0 + \alpha z_\alpha. \end{aligned} \tag{1'}$$

We have named this new form the *two-steps form* of (1). It emphasizes that the present value of the infinite income stream is composed of an immediate annuity, plus the present value of the same income stream started one period later. Similar forms and interpretations can be given to (2) and (3).

Markov Chains in Economic Systems

Consider a Markov chain with an n-order transition matrix $P(n\times n) = [p_{ij}]$. Since the p_{ij} elements are probabilities,

$$\sum_j p_{ij} = 1 \qquad (i = 1, 2, \cdots n). \tag{4}$$

Let the current state of the process—state i—be denoted by a *state vec-*

tor[3] E_i $(1 \times n)$. E_i is the unit row vector with the unity in position i. Given a state vector E_i, the vector E_iP is the probability vector for the states of the process in the succeeding stage. In the stage after that, the probabilities will be $(E_iP)P = E_iP^2$. In general, the probabilities for the tth period constitute the vector E_iP^t. Also, let a rewards row vector $C(1 \times n) = [c_i]$ associate an immediate reward[4] with every state i. The present value of the next period's reward is, therefore, $\alpha E_iPC'$. Thus, if the process continues indefinitely, the expected present value of all future incomes—the worth of the process currently in state i—is

$$\begin{aligned} z_i &= \sum_{t=0}^{\infty} E_i(\alpha P)^t C' \\ &= E_i(I - \alpha P)^{-1} C' \end{aligned} \tag{5}$$

where α is, as previously, the discounting factor.

Utilizing scalar notation, we may introduce the two-steps form of (5):

$$z_i = c_i + \alpha \sum_{j=1}^{n} p_{ij} z_j. \tag{5'}$$

Starting from a state i, the worth of the process is the immediate reward c_i, plus the expected worths of the states of the next stage, discounted one period.

To consider all starting states, we replace E_i by the unit matrix I and write

$$Z' = I(I - \alpha P)^{-1} C' = (I - \alpha P)^{-1} C', \tag{6}$$

where Z is the $(1 \times n)$ vector whose elements are the z_i values of (5).

In terms of the previous section, the case presented here is the discounting case, within the framework of the Markovian model. We shall now make use of the analogy to the breakdown case; this will link us directly to the general theory of Markov chains and provide us with convenient terminology and greater insight. Toward this end, consider a process with a transition matrix T, of the order $n+1$, which can be partitioned:

$$T = \begin{bmatrix} Q & H' \\ 0 & 1 \end{bmatrix}.$$

In T, $H(1 \times n)$ is a probability vector, 0 a zero vector, and 1 a scalar. The Markov chain defined by T consists of two sets of states: one, *transient*, with the n states in Q, and one, the $(n+1)$ state—*ergodic*. Once the process

[3] E_i can be regarded as a particular case of a *state probability vector*.

[4] The assumption in the text is that the reward is associated with the occupation of the state. It is not difficult to incorporate the alternative assumption that the reward is due to a particular transition from state i to state j [7, p. 460].

reaches the ergodic state, it will be *absorbed* there and will never re-enter any of the transient states. The elements of H are, therefore, the probabilities that the process would be transformed from each of the transient states into the ergodic state. Q is the transition matrix of the transient states.

Associated with every transient set—with every matrix Q—is a *fundamental* square matrix, $V=[v_{ij}]$.

$$V = (I - Q)^{-1} = \sum_{t=0}^{\infty} Q^t. \tag{7}$$

The elements v_{ij} indicate the expected number of times that a process, currently in state i, will be in state j before being absorbed in the ergodic state (including the current stage in the count of v_{ii}). To complete the analogy, let every transient state i carry a reward c_i, and the ergodic state represent total breakdown of the system—zero income. Total expected income (*not discounted*) for a process starting in state i, is

$$\begin{aligned} z_i &= \sum_{t=0}^{\infty} E_i Q^t C' \\ &= E_i (I - Q)^{-1} C'. \end{aligned} \tag{8}$$

By defining Q of (7) and (8) as $Q=\alpha P$, we return to the discounting case and may treat the matrix αP as if it were the transient part of a Markov process. Here we shall name the v_{ij} elements of $V=(I-\alpha P)^{-1}$, the *expected discounted* number of times that a process, currently in state i, will be in state j. These numbers are finite, while physically the process will continue for an infinite duration.

Since P is a transition matrix, the sum of every row of αP is α (see equation 4), and therefore all elements of the corresponding H vector are $1-\alpha$, which is also the sum of all rows in the matrix $I-\alpha P$. Hence, total discounted number of stages in any state, starting from state i, is by (A.2) in the Appendix

$$\sum_{j=1}^{n} v_{ij} = 1/(1 - \alpha) \qquad (i = 1, 2, \cdots, n). \tag{9}$$

We can interpret this result, again utilizing the analogy to the breakdown case, as follows: $1-\alpha$ is the probability of breakdown of the system in any stage; therefore, α is the probability of survival. Hence, the total expected number of stages before breakdown will be

$$\sum_{t=0}^{\infty} \alpha^t = 1/(1 - \alpha). \tag{10}$$

The interpretation we gave to the elements of the fundamental matrix V permits the rewriting of (8) as

$$z_i = \sum_{j=1}^{n} v_{ij}c_j \qquad (i = 1, 2, \cdots, n), \tag{3'}$$

which can easily be verified algebraically and interpreted economically.

Programming will be meaningful in those cases in which a certain process can be chosen from several alternatives. Instead of enumerating all possible transition matrices, we consider an *expanded* matrix R $(m\times n) = [p_{ij}^{d(i)}]$, which consists of k_i different probability rows for every state i, $m = \sum_{i=1}^{n} k_i$. The superscript $d(i)$ indicates an *action* to take in state i where $d(i) = 1, 2, \cdots, k_i$. Generally, we shall eliminate, for brevity, the index i of $d(i)$ and write p_{ij}^d. The action indicated by the superscript will affect the transition probabilities (probabilities of failure of equipment, for example, can be affected by actions of maintenance). The immediate reward of the state i is also affected by the action; for example, cost of action is deducted from the gross value of the reward. Thus, the vector C is also expanded and its elements are now c_i^d. An expanded probability matrix R of the dimension 6×2, with the corresponding immediate rewards vector C, is given in Table 1. Thus, in the table, if in state 1 action a_1 is taken, $d(1) = 1$, the transition probabilities are $p_{11}^1 = 0.20$, $p_{12}^1 = 0.80$ and the expected immediate reward is $c_1^1 = \$5.00$.

Table 1. An expanded transition matrix with rewards

State	Actions[a]	Probabilities of transition (Matrix R)		Immediate rewards (Vector C')
		to state 1	to state 2	
State 1	a_1	0.20	0.80	\$5.00
	a_2	0.00	1.00	4.50
	a_3	1.00	0.00	0.00
State 2	b_1	0.60	0.40	\$2.00
	b_2	0.40	0.60	2.30
	b_3	0.00	1.00	0.00

[a] Actions are listed by names. For example, a_1 is the name of the action in state 1 for which $d(1) = 1$.

The Markov process will be determined when a decision vector $D(1\times n)$ is chosen, designating a $d(i)$ value for every i, that is, specifying a policy—an action to take in every possible state.[5] By deciding on a D, one chooses a particular transition matrix P, out of R, for the process at hand and a corresponding vector C of immediate rewards.

Programming for maximal expected income can be performed by the budgeting method—by listing all possible P square matrices out of R, calculating, by (5), expected worth of each, and selecting the one with the

[5] We shall regard the vector D, interchangeably, as either the vector consisting of the indices $d(i)$ or of the names of the actions a_1, b_2, etc.

highest z_i. This might be extremely laborious. Instead, dynamic or linear programming methods may be applied.

Dynamic Programming

In this section we will follow Hadley [7, pp. 454–460], who also provides the proofs for the procedure described here.

To select an optimal decision vector D by the dynamic programming method, start from an arbitrary D, call it $D(1)$, thus selecting a corresponding matrix $P(1)$ and a vector $C(1)$. Now calculate a vector $Z(1)$ of expected present values for all starting states.

$$Z(1)' = [I - \alpha P(1)]^{-1} C(1)' \tag{11}$$
$$= C(1)' + \alpha P(1) Z(1)'.$$

The last line—the two-steps form of (11)—is the matrix form of (5′).

Next, check whether $D(1)$ is optimal. This is done by the following recurrence procedure: define a *test policy* to be the policy $D(1)$ for all future stages but not necessarily for the current one. For the current stage, the test policy associates an alternative action $d(i)$—not necessarily in $D(1)$—with state i. Now evaluate

$$z_i = \max_d \left[c_i^d + \alpha \sum_{j=1}^{n} p_{ij}^d z_j(1) \right] \qquad (i = 1, 2, \cdots, n). \tag{12}$$

A new decision vector $D(2)$ emerges, consisting, for every i, of the $d(i)^*$ element that maximizes the expression in (12). If $D(1)$ is an optimal policy, then $D(2) = D(1)$. If not, calculate

$$Z(2)' = [I - \alpha P(2)]^{-1} C(2)', \tag{13}$$

and repeat (12) and (13) until $D(k) = D(k-1) = D^*$.[6] D^* is the optimal policy which maximizes present value of expected income from the process.

In this procedure, all possible starting states are considered. Thus, D^* is invariant under different starting states—the set of optimal actions to take in every possible state is independent of the current state of the process.

Linear Programming

Our linear programming problem [5] will be

$$\begin{cases} a.\ \max C\Pi' \\ \quad \text{subject to} \\ b.\ M\Pi' = E_i' \\ c.\ \Pi \geq 0. \end{cases} \tag{14}$$

[6] The optimal policy need not be unique; several D vectors might lead to the same maximal present value. It is, however, not difficult to protect the computer program against cycling.

In (14), C is the expanded immediate rewards vector; Π is the solution vector to the linear programming problem; E_i is, as previously, the unit state vector with unity in position i. The matrix $M(n\times m)$ is constructed of the expanded transition matrix R by first expanding a unit matrix to a matrix $J(m\times n)$, which consists of k_i identical E_i unit row vectors for every i, and then

$$M = (J - \alpha R)'. \tag{15}$$

The matrices J, R, and M, for a problem with two states and two actions in each state, are illustrated below.

$$J = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} \qquad \alpha R = \begin{bmatrix} \alpha p_{11}{}^1 & \alpha p_{12}{}^1 \\ \alpha p_{11}{}^2 & \alpha p_{12}{}^2 \\ \alpha p_{21}{}^1 & \alpha p_{22}{}^1 \\ \alpha p_{21}{}^2 & \alpha p_{22}{}^2 \end{bmatrix}$$

$$M = \begin{bmatrix} 1 - \alpha p_{11}{}^1 & 1 - \alpha p_{11}{}^2 & - \alpha p_{21}{}^1 & - \alpha p_{21}{}^2 \\ - \alpha p_{12}{}^1 & - \alpha p_{12}{}^2 & 1 - \alpha p_{22}{}^1 & 1 - \alpha p_{22}{}^2 \end{bmatrix}$$

Table 2 is the simplex table for the example of Table 1. The matrix M constitutes the bulk of the first section—the input–output coefficients—to which a unit matrix of slack variables (artificial activities) was added. The assumption in the table is that the process is started in state 1.

We shall now show that the solution to the linear programming problem (14), like the dynamic programming solution, will select a policy that will maximize expected present value of income from the process at hand.

Following the usual linear programming convention, we add slack variables and partition the vectors Π and C and the matrix M:

$$\Pi = [\Pi_s \;\; \Pi_o \;\; \Pi_1], \qquad C = [C_s \;\; C_o \;\; 0], \qquad M = [M_s \;\; M_o \;\; I], \tag{16}$$

where s is the index of the part in the basis, and o is the index of the part not in the basis. By (14) and (16),

$$M_s\Pi_s' + M_o\Pi_o' = E_i' \tag{17}$$

and

$$\begin{aligned} \Pi_s' &= M_s^{-1}E_i' - M_s^{-1}M_o\Pi_o' \\ &= M_s^{-1}E_i' \end{aligned} \tag{18}$$

since $\Pi_o = 0$.

It was shown by Wolfe and Danzig [9] that the linear programming procedure assures that, in (18), $M_s^{-1} = [(I - \alpha P_s)^{-1}]'$, where P_s is a transition matrix selected from R. This means that there will be exactly one column in M_s for every possible starting state. We repeat, for completeness, the es-

Table 2. First and last simplex sections[a]

				State 1			State 2			"Slacks"	
	C_s	$C\rightarrow$		5.0	4.5	0.0	2.0	2.3	0.0	0	0
		Basis	Π_s	a_1	a_2	a_3	b_1	b_2	b_3	d_1	d_2
First section	0	d_1	1	0.82	1.00	0.10	−0.54	−0.36	0.00	1	0
	0	d_2	0	−0.72	−0.90	0	0.64	0.46	0.10	0	1
Last section	5.0	a_1	4.706	1.00	1.133	0.471	0.00	0.132	0.397	4.706	3.971
	2.0	b_1	5.294	0.00	−0.133	0.529	1.00	0.868	0.603	5.294	6.029
		z_j	34.118	5.0	5.397	3.412	2.0	2.397	3.191	34.118	31.912
		z_j-c_j		0.0	0.897	3.412	0.0	0.097	3.191	34.118	31.912

[a] Based on Table 1, with $\alpha = 0.9$. For additional explanations see text.

sence of the proof: since $E_i \geq 0$ and $\Pi_o = 0$, then (14.c) and (17) can be simultaneously maintained only if every row of M_s contains at least one nonnegative element. The only positive elements in M are of the form $1-\alpha p_{ii}^d$, of which there is one in every column. The matrix M_s is of the order n; it has n columns, each with exactly one element of the form $1-\alpha p_{ii}^d$. It also has n rows, and must, as stated, have at least one nonnegative element in every row. Hence, it will have exactly one element of the form $1-\alpha p_{ii}^d$ in every row. Therefore, there will be exactly one element $1-\alpha p_{ii}^d$ in every row and column of M_s, which completes the proof.

Equation (18) can now be written as

$$\Pi_s' = [(I - \alpha P_s)^{-1}]'E_i', \tag{19}$$

and, therefore,

$$C\Pi' = C[(I - \alpha P_s)^{-1}]'E_i'. \tag{20}$$

Comparing (20) to (5), we see that $C\Pi'$ is the worth of a Markov process currently in state i. The maximal value of $C\Pi'$—the value of the objective function in the solution to (14)—is the maximal worth of a system of Markov processes.

The solution to (14) determines a policy vector, D_s, which can be constructed by observing the vectors in the basis. It stems from Property 7 of the next section that D_s is not affected by the starting state of the process. Thus, D_s of linear programming, like D^* of the dynamic programming solution, is an optimal policy vector. The same expected maximal present value is reached by the linear and the dynamic programming methods and, if there is only one unique optimal policy vector, then $D_s = D^*$.

In the next section we shall investigate some of the properties and possible interpretations of the simplex routine and elaborate further on the lines of similarity between the dynamic and the linear programming methods.

Properties of the Simplex Solution

It will be convenient if we state here the criterion function of the simplex routine—the $Z-C$ row vector—

$$\begin{aligned} Z - C &= C_s M_s^{-1}[M_s \ M_o \ I] - [C_s \ C_o \ 0] \\ &= C_s[I \ M_s^{-1}M_o \ M_s^{-1}] - [C_s \ C_o \ 0] \\ &= [0 \ C_s M_s^{-1} M_o - C_o \ C_s M_s^{-1}]. \end{aligned} \tag{21}$$

Reference to the element of (21) is made in the discussion that follows.

Property 1

As was previously explained, by programming for a D_s we select a transition matrix P_s and $M_s = (I - \alpha P_s)'$. Therefore, by (7),

$$M_s^{-1} = [(I - \alpha P_s)^{-1}]' \tag{22}$$
$$= [(I - Q)^{-1}]'$$
$$= V',$$

where V is the fundamental matrix associated with the "transient" matrix αP_s. Thus, in Table 2, consistent with the terminology introduced in the section "Markov Chains in Economic Systems," the expected discounted number of times that a process, currently in state 2, will be in state 1 is 3.971, and in state 2 is 6.029.

Property 2

By equations (22) and (9), the sums of the columns of M_s^{-1} are $1/(1-\alpha)$. In Table 2, $\alpha=0.9$, $1/(1-\alpha)=10$, and the sums are

$$\text{column } d_1\text{:}\quad 4.706 + 5.294 = 10$$
$$\text{column } d_2\text{:}\quad 3.971 + 6.029 = 10.$$

Property 3

Let u_{ik}^o be the simplex table element for row i, state k, and o a value for $d(k)$ outside the basis. Thus u_{ik}^o is defined by $M_s^{-1}M_o = [u_{ik}^o]$. For example, in Table 2, column b_2, last section, $u_{12}^2 = 0.132$.

By Property 1, $M_s^{-1}M_o = V'M_o$. Therefore, in scalar notations and denoting by p_{ij}^o the transition probabilities in M_o (thus p_{ij}^o is the probability of transition from i to j with action o),

$$u_{ik}^o = -\sum_{j\neq k} v_{ji}\alpha p_{kj}^o + v_{ki}(1 - \alpha p_{kk}^o) \tag{23}$$
$$= v_{ki} - \alpha \sum_j p_{kj}^o v_{ji} \qquad (k = 1, 2, \cdots, n).$$

Examining the last line—the two-steps form of (23)—one recognizes that u_{ik}^o is the difference between (*a*) the expected discounted number of times that a process, currently in state k, will be in state i—if the present policy is adopted (v_{ki}), and (*b*) the expected discounted number of times that a process starting in state k will be in state i if the test policy, with action $d(k)=o$ for the current stage and the basic policy for all future stages, is adopted. Action o is taken *once* and the basic policy D_s is followed for all other stages. Hence, u_{ik}^o is the marginal rate of substitution of the present (basic) policy to the *alternative policy* with action o for state k in all stages. The substitution is in the decision vector D, and it is "marginal" in that the alternative policy is adopted for only one stage—the current stage.

Property 4

The sum of the elements in every column of the simplex table is unity.

For actions in the basis this is obvious—these columns are unit columns. For actions not in the basis, the sums of the elements of the matrix $M_s^{-1}M_o$ are also unity. Since the sum of every column of the matrix M is $1-\alpha$, therefore, by *A.2* in the Appendix, the sums of the columns of M_s^{-1} are all $1/(1-\alpha)$. Hence, by *A.1* of the Appendix, the column sums in $M_s^{-1}M_o$ are

$$(1-\alpha)/(1-\alpha) = 1.$$

For example, in Table 2, column a_1, the sum is

$$1.133 - 0.133 = 1.0.$$

Making use of (23), we write the column sum as

$$\begin{aligned} (24) \qquad \sum_i u_{ik}^o &= \sum_i \left(v_{ki} - \alpha \sum_i p_{kj}^o v_{ji} \right) \\ &= 1 \qquad\qquad (k = 1, 2, \cdots, n). \end{aligned}$$

The sum in the right-hand side of the first line of (24) is the difference in the total discounted number of stages under the two policies—the basic policy and the test policy. In general, the total discounted number of stages is the same under any policy (Property 2). The difference in (24), which is unity, stems from the fact that the count of stages for the basic policy includes the current stage (the sum in equation 7, for example, goes from *zero* to infinity), whereas for the test policy the count starts from the next stage and omits the current one.

Property 5

The dual values, the elements of the row vector $C_sM_s^{-1}$, are the values of the alternative objective function, under the basic policy, for all possible starting states. If we write the element k of this vector as z_k^s and denote by c_i^s the element of C_s, the dual values are

$$(25) \qquad z_k^s = \sum_i c_i^s v_{ki} \qquad (k = 1, 2, \cdots, n),$$

which is exactly (8′). In the table, $z_1^s = \$34.118$—the value of the objective function for a process starting in state 1; $z_2^s = \$31.912$—the objective function for a process starting in state 2.

Property 6

The elements in the $Z-C$ row for actions not in the basis (21) are $C_sM_s^{-1}M_o - C_o$.

For a state k and action o, we shall denote these elements in the criterion function as $z_k^o - c_k^o$ and write in scalar notation

$$(26)\quad z_k{}^o - c_k{}^o = -\sum_{j \neq k} \alpha p_{kj}{}^o z_j{}^s + z_k{}^s(1 - \alpha p_{kk}{}^o) - c_k{}^o$$

$$= z_k{}^s - \left(c_k{}^o + \alpha \sum_j p_{kj}{}^o z_j{}^s\right) \qquad (k = 1, 2, \cdots, n).$$

The term in the parenthesis in the second version of (26) is the two-steps form of the objective function, for a process in state k, under the test policy. The alternative policy—with action o for state k—will be adopted throughout all future periods if the value of (26) is negative, that is, if the test policy is superior to the basic policy. Since the process lasts forever, if action o for state k is superior for the current state it will also be superior in any future state. This principle is, of course, the rationale behind the dynamic programming procedure, outlined in the section, "Dynamic Programming." It is evident now that the criteria for changing a policy, from iteration to iteration, are the same in the linear and in the dynamic programming techniques. The one difference, however, is that in the simplex method of linear programming one element of D is replaced at a time, whereas in dynamic programming a new vector D is constructed at every iteration, which can differ from the previous policy by several elements.

Property 7

The optimal policy is not affected by the starting state of the process. To see this, one must show that a change of E_i to E_j will not alter the basis of the linear programming solution. Denote a solution vector associated with the starting state i by $\Pi_s(i)$. We know [5, p. 133] that

$$(27)\qquad \Pi_s(i) = M_s^{-1}E_i' \geq 0$$

is a feasible solution for a starting state i, and that a change of E_i to E_j will not alter the optimal basis, M_s, if, in addition to (27),

$$(28)\qquad \Pi_s(j) = M_s^{-1}E_j' \geq 0.$$

The condition in (28) is maintained, since all elements in M_s^{-1}—the v_{ij} elements—are nonnegative.

Extensions and Applications

A multiprocess system

Generally an enterprise will not be a single process but will constitute a system of many processes—fields in a farm, for example, or machines in a factory, or units of an operating army. If we assume that these processes are independent and let e_i be the number of processes, at present in state i, in an enterprise, then the total worth of the enterprise is

$$W = \sum_{i=1}^{n} e_i z_i^s, \tag{29}$$

where z_i^s is defined as in (25). W can be easily calculated from the dual values of the linear programming solution.

Alternatively, a direct approach can be implemented: define a state vector $E(1\times m)$ whose elements are the e_i values (the vector E_i is now a particular value of E), and instead of (14) solve as follows:

$$\begin{cases} a.\ a \max C\Pi' \\ \quad \text{subject to} \\ b.\ M\Pi' = E' \\ c.\ \Pi \geq 0. \end{cases} \tag{14'}$$

The maximal value of the objective function in (14′) will be the W of (29).

A decomposable system

Up to now, we have assumed a system that is not decomposable. This need not be the only case. If the matrix M is decomposable, and if, say, $E_i = E_1$, then (14.b) will be

$$\begin{bmatrix} M_1 & 0 \\ & \\ 0 & M_2 \end{bmatrix} \begin{bmatrix} \Pi_1' \\ \\ \Pi_2' \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{bmatrix}. \tag{30}$$

The elements of Π_2 in (30) must be zeros by the formulation of the problem. The second chain will not be programmed at all.

To avoid this difficulty, it has been suggested [4, 7] that, even in cases of single-process systems, (14′) be solved with an arbitrary nonzero E—the vector on the right-hand side. The optimal policy is not affected by this device. The calculated value of the objective function depends, of course, on the selected values for E.

An inferior state

Another assumption was that chains were regular, that their fundamental matrices had no zero entries, that all states were probable far enough in the future. In practice, one might encounter states which are economically inferior and can be avoided—small inventories, for example, or old machinery. If it is possible, and the appropriate actions are specified, a policy will be selected that will avoid the inferior states. If the process is started in such a state, it will leave that state in one or a few periods. As an example, consider, in Table 3, a new expanded matrix constructed from Table 1 by eliminating, for simplicity, a_3 and b_3 and adding a third state.

Table 3. An expanded R matrix with an inferior state

States	Actions	Probabilities of transition			Immediate rewards
		to state 1	to state 2	to state 3	
State 1	a_1	0.20	0.80	0.00	\$5.00
	a^2	0.00	1.00	0.00	4.50
	a^4	0.00	0.00	1.00	0.00
State 2	b_1	0.60	0.40	0.00	\$2.00
	b_2	0.40	0.60	0.00	2.30
	b^4	0.80	0.00	0.20	1.00
State 3	c_1	1.00	0.00	0.00	\$4.00
	c_2	0.10	0.70	0.20	4.50

Programming,[7] one finds that the optimal policy vector, D_s, of this process consists of a_1, b_1, and c_1 and the corresponding transition matrix is, therefore,

$$P_s = \begin{bmatrix} 0.20 & 0.80 & 0 \\ 0.60 & 0.40 & 0 \\ 1.00 & 0.00 & 0 \end{bmatrix}.$$

An absorbing state

As experience teaches, some policies may lead to irreversible, and sometimes destructive, results. A particular crop rotation will not protect the soil and a heavy rain may cause erosion and destroy all future possibility of cultivating the field. A monopolist may charge high prices that will breed rival firms. These are breakdown cases whose Markov matrices are like T of the section "Markov Chains in Economic Systems." Some reflection, and the example below, will show that "destructive" policies may sometimes be optimal. In fact, whether they will be chosen or rejected depends, all other things being the same, on the discounting rate—the higher the rate of interest, the more probable it is that a "suicidal" policy, which yields high income until destruction, will be adopted.

As an example, consider the expanded R matrix given in Table 4. Note that the reward for the third, absorbing state is zero and that no possible action is attached to this state, which stands for the collapse of the economic system. The optimal policies for this system are listed in Table 5. Also given in Table 5 are the probabilities that a process starting in state 1 will be in any of the states at some specified t period. Once action a_1 is introduced, the process must end in state 3.

[7] We took $\alpha = 0.9$ in this case too.

Table 4. Expanded matrix with rewards, possible breakdown case

States	Actions	Probabilities of transition			Immediate rewards
		to state 1	to state 2	to state 3	
State 1	a_1 a_2	0.40 0.70	0.55 0.30	0.05 0.00	\$6.00 4.00
State 2	b_1 b_2	0.30 0.40	0.50 0.60	0.10 0.00	\$5.00 3.00
State 3		0.00	0.00	1.00	\$0.00

The right-hand section of the table lists the expected number of times (not discounted) that the process will be in any of the states, under the optimal policies. The numbers in the parentheses are the standard deviations of these numbers [8, Chap. 3]. Thus, in Table 5, in the lower section, under policy a_1b_1, the number of times that a process starting in state 1 will be in state 2 is 7.35 ± 7.49: the standard deviations are quite high in relation to the expected values. Under policy a_2b_2, the process will never reach the absorbing state and will be an infinite number of times in both states 1 and 2.

Depletion and deterioration

The last section dealt with a system with a possible breakdown case. More probable than the sudden "death" or collapse of the economic process is the possibility of depletion or decay of productivity—the deterioration case. A particular crop rotation will gradually impoverish the field; pumping of coastal groundwater damages the quality of that source; a certain maintenance routine results in a gradual reduction of income from an asset. In some respects depletion and deterioration are "historical" phenomena, alien to the Markovian assumption of independence. However, by utilizing the analogy of the deterioration case to the other two cases (in the section "Income Streams"), one may incorporate realistic types of these phenomena into our model.

Assume, for simplicity, a zero rate of interest, namely $\alpha = 1$, and let income, productivity, service, etc. from the economic process deteriorate at a rate $1-\beta (0<\beta<1)$ per period. Expected, not discounted, worth of the income stream is

$$(31) \qquad z_i = \sum_{t=0}^{\infty} E_i(\beta P)^t C' = E_i(I - \beta P)^{-1} C'.$$

More interesting will be the case in which the rate of deterioration is not

Table 5. Characteristics of optimal policies for data in Table 4

Range of interest rate	State	Optimal policy	Transition matrix			Probability of state (E_1p^t)							Expected number of transitions in state (standard deviation)	
						$t=0$	1	2	3	5	10	∞	State 1	State 2
percent														
0–10	1	a_2	0.70	0.30	0.00	1.00	0.70	0.610	0.583	0.572	0.571	0.571	∞	∞
	2	b_2	0.40	0.60	0.00	0.00	0.30	0.390	0.417	0.428	0.429	0.429	∞	∞
	3		0.00	0.00	1.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0	0
11–20	1	a_1	0.40	0.55	0.05	1.00	0.40	0.380	0.372	0.357	0.321	0.000	20 (19.5)	27.5 (25.8)
	2	b_2	0.40	0.60	0.00	0.00	0.55	0.550	0.539	0.517	0.465	0.000	20 (19.5)	30.0 (29.5)
	3		0.00	0.00	1.00	0.00	0.05	0.070	0.089	0.126	0.214	1.000	∞	∞
21 and up	1	a_1	0.40	0.55	0.05	1.00	0.40	0.325	0.295	0.248	0.162	0.000	5.35 (3.64)	7.35 (7.49)
	2	b_1	0.30	0.60	0.10	0.00	0.55	0.550	0.509	0.429	0.280	0.000	4.00 (4.77)	8.00 (7.48)
	3		0.00	0.00	1.00	0.00	0.05	0.125	0.196	0.323	0.558	1.000	∞	∞

just one rate for the process but differs from state to state. Now, at the period in which the process occupies state i, its productivity deteriorates at the rate β_i. For example, expected income from the next stage of a process, currently in state i, is $\beta_i \sum_j p_{ij}c_j = \sum_j \beta_i p_{ij}c_j$, or, in matrix notation, E_iBPC', where B is a diagonal matrix with β_i on the diagonal and zeros elsewhere.

Expected value of an everlasting process is, therefore,

$$(32) \qquad z_i = \sum_{t=0}^{\infty} E_i(BP)^t C' = E_i(I - BP)^{-1}C'.$$

It is easily seen now that to allow nonzero rates of interest, one simply incorporates α in (32) to form

$$(33) \qquad z_i = E_i(I - \alpha BP)^{-1}C'.$$

For alternative policies and programming, B is expanded to allow $\beta_i^{(di)}$—deterioration is a function of state and action.

Growth and appreciation

If deterioration is represented by $\beta_i < 1$, growing productivity or appreciation can be represented by $\beta_i > 1$. In fact, (33) applies to cases of appreciation so long as $\alpha\beta_i^d < 1$ for all i and d. If $\alpha\beta_i^d \geq 1$ for some i and d, the existence of the inverse matrix of (33) is not assured; that is, z_i in (33) need not be finite. Programming is, however, still possible by, for example, considering a finite horizon. We shall not pursue this subject further here.

Concluding Remarks

We have tried to show that the Markov chain model may be used in a variety of economic applications. The discussion of the linear programming solution has facilitated, we trust, better understanding of the Markov process and of the rival dynamic programming method. An unsolved problem is that of the incorporation of the regular linear programming limitations and requirements into the present model. The difficulty lies in the fact that the solutions to the Markovian systems are in terms of expected numbers, while the actual magnitudes will change from period to period and may under- or overshoot limitations and requirements, if such exist. We hope to return to this question in the future.

Appendix

A. 1

Let $B = [b_{ij}]$ and $F = [f_{ij}]$ be n-order square matrices with constant column sums: $\sum_i b_{ij} = s$ $(j = 1, 2, \cdots, n)$ and $\sum_i f_{ij} = t$ $(j = 1, 2, \cdots, n)$. If

we let the matrix $G=[g_{ij}]$ be the product matrix of B and $F(G=BF)$, then the column sums of G are all st.

Proof:

$$\begin{aligned} \sum_i g_{ij} &= \sum_i \sum_k b_{ik} f_{kj} \\ &= \sum_k f_{kj} \sum_i b_{ik} \\ &= s \sum_k f_k \\ &= st. \end{aligned}$$

A. 2

If we let $H=[h_{ij}]$ be the inverse matrix of $B(H=B^{-1})$, then $\sum_i h_{ij}=1/s$ $(j=1, 2, \cdots, n)$.

Proof:

$$\begin{aligned} BH &= I \\ \sum_i \sum_j b_{ij} h_{jk} &= 1 \\ \sum_j h_{jk} \sum_i b_{ij} &= 1 \\ s \sum_j h_{jk} &= 1 \\ \sum_j h_{jk} &= 1/s. \end{aligned}$$

References

[1] BURT, OSCAR R., AND JOHN R. ALLISON, "Farm Management Decisions with Dynamic Programming," *J. Farm Econ.* 45:121–136, Feb. 1963.

[2] ———, "Optimal Replacement Under Risk," *J. Farm Econ.* 47:324–346, May 1965.

[3] DE GHELLINCK, GUY T., AND GARY D. EPPEN, "Linear Programming Solutions for Separable Markovian Decision Problems," *Mgt. Sci.* 13:371–394, Jan. 1967.

[4] D'EPENOUX, F., "A Probabilistic Production and Inventory Problem," *Mgt. Sci.* 10:98–108, 1963.

[5] GASS, SAUL I., *Linear Programming: Methods and Applications*, 2d ed., New York, McGraw-Hill Book Co., 1964.

[6] HOWARD, R., *Dynamic Programming and Markov Processes*, Cambridge, Mass., Technology Press, 1960.

[7] HADLEY, G., *Non-Linear and Dynamic Programming*, Reading, Mass., Addison-Wesley Publishing Co., Inc., 1964.

[8] KEMENY, JOHN G., AND J. LAURIE SNELL, *Finite Markov Chains*, Princeton, N. J., D. Van Nostrand Co., Inc., 1960.

[9] WOLFE, PHILIP, AND G. B. DANZIG, "Linear Programming in a Markov Chain," *Operations Res.* 10:702–710, 1962.

Economic Considerations in Response Research

J. R. ANDERSON AND JOHN L. DILLON*

The general neglect of economic considerations in response research is noted. Following the listing of several factors which influence investment in response research, a framework is developed in which knowledge of a process is viewed in terms of the expected value and variance of profits. A Bayesian scheme for incorporating additional information in posterior analysis is outlined. Worth of additional information is judged in terms of utility. The scheme is used to show how the value of obtaining additional information can be ascertained ex ante in preposterior analysis by way of a Monte-Carlo approach. Both posterior and preposterior analyses are illustrated through a soybean-fertilizer process. In this empirical example, the effects of using different experimental designs of varying size are examined.

FOR A decade or more, agricultural economists (production variety) have been urging agricultural scientists to estimate crop and livestock production functions. Such estimates, we have argued, will enable farmers to make better decisions on input and output levels in their crop and livestock production. At the same time, no overt attention has been given to the economics of conducting such research. No concrete guidance has been given as to the extent to which response processes might best be investigated in terms of costs and returns.

Seemingly an act of professional faith, our evangelizing has implied that production function estimation based on experiments with "many factors at many levels rather than many replications of a few factors" will give information of greater value than its cost. Or else, in chasing the MVP of the ith factor, we have ignored the MVP of response research itself. It is as if the mere organization of data in a form aesthetically suited to applying production economics principles has been an end in itself. Either of these implications leaves much to be desired. Here we hope to make a start towards rectifying this situation by providing some appreciation of the economics of response research.

To make the problem tractable, we confine our attention to the situation of a farmer interested in investing in his own response research. Thus, by taking the problem out of the public arena, we avoid the peripheral complications of, on the cost side, having to consider fiscal policies for the financing of public research, and interrelatedly, on the revenue side, having to assess the aggregate social benefits of public response research. Not that these macro problems are unimportant, but they can hardly be appraised without first having an appreciation of response research in its micro aspects.

* With the usual caveat, we are indebted to John Phillips for critical comments.

J. R. ANDERSON AND JOHN L. DILLON *are, respectively, research fellow and professor in the Department of Farm Management, University of New England, Armidale, Australia.*

Nor will we explicitly consider the question of optimal investment in response research by input suppliers such as fertilizer and feed manufacturers. Such factor suppliers will generally measure their research benefits through increases in demand for their products. Since input demand will be increased only if the research implies higher optimal rates of input use, the factor suppliers' investment decision problem is somewhat different (though not too much so) from that of assessing research aimed at increasing farmer profits.

In the framework developed below, response research is judged of some value to the farmer if it indicates optimal input rates which increase his expected profits and/or decrease his risk as measured by the variance of profits. Intuitively then, we know that several factors will be important in influencing optimal investment in response experiments. To these we now turn.

Economic Influences on Investment in Response Research

To what extent a producer might best invest in response research will depend largely on his prior knowledge, his attitude to risk, the life of the knowledge gained, the size of the universe to which it applies, and the cost of the research.

Prior knowledge

Prior knowledge is what is known of the process before the experimental work being contemplated is undertaken. Imperfect prior knowledge will imply losses from nonoptimal operation, which, depending on the process, may be of economic consequence. Clearly, at some stage, diminishing returns will characterize any investment in response research aimed at ascertaining best operating conditions, since, as a state of perfect information is approached, additions to knowledge and potential benefits become successively smaller. The approach to full information via possible stages of prior knowledge might be conveniently characterized by the following sequence of information categories:

1. Absolute ignorance.
2. Slight knowledge of some or all of the operative factors in the process.
3. First-hand experience with the operative factors at one or more traditional but not necessarily optimal levels.
4. Knowledge from experiments conducted on the process elsewhere, preferably in a similar environment, (*a*) with only summary statistical information (for example, regression coefficients, standard errors, and error variance) available, or (*b*) with all data and analyses available.
5. Full knowledge of data and analyses from prior local experiments.

For most crop and livestock production processes, it would be relatively easy to move from knowledge situations 1, 2, or 3 up to 4*a*. Our analysis,

however, will deal with situation 5, thereby enabling us to avoid the complications of spatial variability due to heterogeneity over space in such fixed factors as soil, climate, and management.

Attitude to risk

Because people differ in their attitudes to risk, other things being equal, it is unlikely that the same amount of experimentation will be optimal for all. Different farmers will attach differing weights to the expected profit and risk (that is, profit variance) aspects of a response process. For an individual farmer, these risk attitudes can be summarized in a utility function, or equivalently (assuming that only the first two moments of the probability distribution of profits are important) in a set of indifference relations in the expected value–variance space of profits from possible experimental policies [5]. Although the empirical estimation of producers' utility functions is still somewhat imperfect, real progress has been made recently in this area [6, 7]. We anticipate that, at some future time, utility functions may be widely used in solving risky decision problems.

Life of experimental knowledge

From a public viewpoint, an important aspect of the economics of response research is the extent to which farmers use the knowledge gained from such research—an extension problem. This consideration vanishes through our assumption that the farmer pays for his own response research and fully exploits the knowledge gained. But a key factor is the period for which the knowledge acquired remains pertinent, or, alternatively, the frequency with which the experiments must be performed so as to maintain the process in optimal adjustment. We shall be concerned with the simple situation in which the experiments will be relevant for farmer decision-making for a specified period of time, although, of course, this time horizon and the product and factor prices over it will seldom be known with certainty.

Size of process universe

A major determinant of unit research costs is the size of universe, denoted by A, to which the response research relates. A, for example, might be specified in terms of acreage or herd size over some specified time horizon or number of runs of the process. For the farmer–experimenter, the size of A will depend on the homogeneity of his productive resources (soil, for example), the size of the enterprise, and the type of experiment. For example, a controlled-survey approach [4] will generally relate to a considerably larger universe than a typical small-plot experiment.

Research costs

A multitude of factors will obviously influence the costs of response experiments. Among the more important are plot size and experimental design (for example, a composite or a factorial design [10]). The number of factor levels used will also influence estimated process variance [2, p. 170].

A further pertinent factor in considering a response investigation in isolation is the opportunity cost of the research funds—either in other research, or, for the producer, in some other process. Likewise, fund constraints may cause the producer to use lower factor rates (and consequently to expect lower profits) than those he would use in the unconstrained situation which we will discuss.

A Formal Framework

In discussing the economics of response research, we need not be concerned with the case of absolute ignorance, since some exploratory work would be required before anything useful could be said about the value of "additional" information on the process. Rather than deal with the several categories of prior knowledge, we single out an important case to illustrate the analysis—namely, when an experiment of local relevance has been conducted previously and its full data are available.

First we illustrate the ex post incorporation and evaluation of additional experimentation—posterior analysis. Then we consider the more interesting problem of preposterior analysis—that is, examining the value of further experiments before they are undertaken.

Posterior analysis

The usual formulation and notation of the normal linear regression model is followed, with a few modifications. The process under investigation is specified on a technical unit basis as

$$Y = f(x_1, x_2, \cdots, x_m)$$

and is assumed to be adequately represented by a quadratic polynomial in the m input factors. The polynomial vector $(1, x_1, \cdots, x_m, x_{11}, \cdots, x_{jh}, \cdots, x_{mm})$ is denoted by w^t and corresponds to the input vector $(x_1, x_2, \cdots, x_m)$ denoted by x^t. The vector w contains k terms where $k=(m+2)(m+1)/2$. For n observations, the n equations,

$$Y_i = \beta_0 + \sum \beta_j x_j + \sum \beta_{jh} x_j x_h + u_i \qquad (h \geq j),$$

can be set out compactly in matrix form as

$$Y = X\beta + u.$$

We assume that the disturbance terms u_i are normally and independently distributed, with mean zero and variance σ^2, and that n is greater than k, the number of coefficients to be estimated. The least-squares estimator of β,

$$b = Z^{-1}X^tY,$$

where $Z = X^tX$, is then the best linear unbiased estimate and we have predicted yield

$$y = Xb$$

with

$$\text{var}(b) = \sigma^2 Z^{-1}.$$

An estimate of σ^2 is given by

$$s^2 = e^te/(n - k)$$

where $e = Y - Xb$.

Throughout, we follow the scheme of Raiffa and Schlaifer [9] in denoting prior information by a single prime, the sample information by no prime, and posterior information by a double prime.

Product price p_y and the factor prices

$$p^t = (p_1, p_2, \cdots, p_m)$$

are introduced in a profit function,

$$\pi = p_y y - p^t x,$$

which provides a convenient means of studying the economics of investigating the response process. When a profit function is maximized, the optimal x, y, and π are labelled with an asterisk.

The costless prior knowledge based on n' observations can be summarized in the response function, with coefficients estimated as

$$b' = Z'^{-1}X'^tY'$$

and with variance given by

$$\text{var}(b') = s'^2 Z'^{-1}.$$

This estimated function implies x'^*, for which we have expected profit

$$E(\pi'^*) = p_y w'^{*t} b' - p^t x'^*,$$

variance of predicted yield at the prior optimal rates

$$V(y'^*) = s'^2(1 + w'^{*t}Z'^{-1}w'^*),$$

and variance of profit

$$V(\pi'^*) = p_y^2 V(y'^*).$$

Aggregating these profit measures over the farmer's process universe A to give total profit P, we have

$$E(P') = AE(\pi'^*)$$

and

$$V(P') = A^2 V(\pi'^*).$$

Note that $E(P')$ does not involve any cost of experimentation, since the n' prior observations and their analysis are assumed available without cost.

A further experiment of n observations is now combined along Bayesian lines [9, p. 343] with the prior information so that the posterior measures relevant to ex post appraisal of this further experiment are given by

$$\begin{aligned} Z'' &= Z' + Z \\ b'' &= Z''^{-1}(Z'b' + Zb) \\ &= Z''^{-1}(Z'b' + X^tY) \end{aligned}$$

and, if Z', Z, and Z'' are all of rank k,

$$\begin{aligned} s''^2 &= [1/(n'' - k)][Y'^tY' + Y^tY - b''^tX''^tY''] \\ &= [1/(n'' - k)][(n' - k)s'^2 + b'^tZ'b' + (n - k)s^2 \\ &\quad + b^tZb - b''^tZ''b''] \end{aligned}$$

where

$$n'' = n' + n.$$

We can now determine the posterior optimal rates, x''^*, and thence

$$\begin{aligned} E(\pi''^*) &= p_y w''^{*t} b'' - p^t x''^*, \\ V(y''^*) &= s''^2(1 + w''^{*t} Z''^{-1} w''^*), \end{aligned}$$

and

$$V(\pi''^*) = p_y^2 V(y''^*).$$

Hence, across the universe of relevance for the process, we have

$$E(P'') = AE(\pi''^*) - C(n)$$

and

$$V(P'') = A^2 V(\pi''^*),$$

where $C(n)$ is the cost of generating and analyzing the set of n experimental observations.

In evaluating the worth of additional experimentation ex post, the com-

parison must be made in terms of the best information available, namely the posterior information, so that the best assessment possible is made of the profitability (utility) of the process with and without the extra experimental information. That is, $E(P'')$ and $V(P'')$ are compared not with $E(P')$ and $V(P')$ but rather with the $E-V$ measures computed from the posterior function and variances based on $n'+n$ observations with input levels at the *prior* optimal rates x'^*. We designate these as posterior $E(P')$ and posterior $V(P')$, respectively. Then, from the farmer's expected utility function $U(E, V)$, we can say that the extra experiment has been worthwhile if the utility $U(E'', V''|x''^*)$ corresponding to $[E(P''), V(P'')]$ is greater than the utility $U(E'', V''|x'^*)$ corresponding to [posterior $E(P')$, posterior $V(P')$].

There is no reason why the general scheme for posterior analysis outlined above should not be used in ex post assessment of experimental work on response processes. If the last experiment conducted in a series has not proved economical, it is unlikely that further similar work will do so. However, when past experiments have been worthwhile, we must determine whether more work will be economical, and, if so, how much is optimal. This situation implies preposterior analysis.

Preposterior analysis

In preposterior analysis we are interested in assessing the value of experiments before they are undertaken so that an appropriate amount of experimentation can be determined. Methods for determining optimal sample size for more simple situations, such as two-action problems with linear costs, are well developed [11]. However, preposterior analysis for regression models has so far received only limited attention (notably in Pratt *et al.* [8]) and, to the best of our knowledge, no attention at all in the particular context of agricultural response processes. Of course, as Havlicek and Seagraves [3] have pointed out, if profitability of a process is not very sensitive to changes in the input rates, there will be little value in obtaining more precise knowledge of the process.

The only contribution to the economics of investigating response appears to be that of Yates [12] (extended slightly by Finney [2]). By assuming a quadratic response function, Yates showed, for the case of a single variable factor, that the expected loss of profit from nonoptimal operation was proportional to the variance of the estimated optimal rate. His "optimal" amount of experimentation was, then, that which minimized the sum of expected loss over the relevant universe and the cost of the experiments. While Yates's analysis is unsatisfactory in several respects, notably (*a*) the absence of consideration of the precision of knowledge and (*b*) overestimation of benefits because he uses the expected value of perfect information rather than the expected value of sample information, this work does not seem to have received the attention it deserves of economists.

best operating conditions would probably be well spent. Still, the value of the knowledge gained will likely be very high only when very little prior information is available. In terms of the limited funds available to society for research, the expected opportunity cost of foregone alternatives may be of sufficient magnitude to dictate a channeling of funds to research which is not aimed merely at the further refinement of best operating specifications for crop and livestock response processes that are already well appreciated. For such processes, farmers may already, by trial and error procedures, be fairly close to best operating conditions.

The simple framework sketched might prove useful for assessing the economics of many response investigations. Rather than being the last word, we hope these initial remarks may stimulate further deserved attention to this area. Many inherent difficulties remain, especially in terms of extending the analysis to the public domain. Certainly, production economists should be aware of these problems as a natural extension of their dual responsibilities for (*a*) encouraging the development of research whose results are amenable to economic analysis and appraisal, and (*b*) assisting in the rational allocation of research resources.

References

[1] BRACKEN, J., AND R. M. SOLAND, "Statistical Decision Analysis of Stochastic Linear Programming Problems," *Naval Res. Log. Quart.* 13:205–225, June 1966.

[2] FINNEY, D. J., *An Introduction to the Theory of Experimental Design*, Chicago, University of Chicago Press, 1960.

[3] HAVLICEK, J. JR., AND J. A. SEAGRAVES, "The 'Cost of the Wrong Decision' as a Guide in Production Research," *J. Farm Econ.* 44:157–168, May 1962.

[4] HOFFNAR, B. R., AND G. L. JOHNSON, *Summary and Evaluation of the Co-operative Agronomic–Economic Experimentation at Michigan State University*, Michigan Agr. Exp. Sta. Res. Bul. 11, 1966.

[5] MARKOWITZ, H. M., *Portfolio Selection: Efficient Diversification of Investments*, New York, John Wiley and Sons, 1959.

[6] OFFICER, R. R., AND A. N. HALTER, "Utility Analysis in a Practical Setting," to be published in *Am. J. Agr. Econ.*, 1968.

[7] OFFICER, R. R., A. N. HALTER, and J. L. DILLON, "Risk, Utility and the Palatability of Extension Advice to Farmer Groups," to be published in *Australian J. Agr. Econ.*, Dec. 1967.

[8] PRATT, J. W., H. RAIFFA, AND R. SCHLAIFER, *Introduction to Statistical Decision Theory*, New York, McGraw-Hill Book Company, 1965.

[9] RAIFFA, H., AND R. SCHLAIFER, *Applied Statistical Decision Theory*, Boston, Division of Research, Harvard Business School, 1961.

[10] ROBINSON, P., AND K. F. NIELSEN, "Composite Designs in Agricultural Research," *Canadian J. Soil Sci.* 40:168–176, Aug. 1960.

[11] SCHLAIFER, R., *Probability and Statistics for Business Decisions*, New York, McGraw-Hill Book Company, 1959.

[12] YATES, F., "Principles Governing the Amount of Experimentation in Developmental Work," *Nature* 170:138–140, July 1952.

manner, if the price index fell by one point, the issues declined by the same amount" [5, p. 3]. Similarly, if the prices in the fair price shops are raised, some consumers will shift from them to the open market, so the open market prices will rise and the new equilibrium between the two prices will be established at a higher level [5, p. 5].

In India, the easy availability of cereals under P.L. 480 has made the fair price shops appear to be more a relief than a marketing agency. The retail price of wheat at fair price shops remained almost fixed at Rs. 40.00 per quintal up to the end of 1964. Consequently, there was a marked difference between the prices at the fair price shops and those in the open market, as shown in Table 1.

the deficit states [3, p. 51]. It has been observed that even during the better crop years (1960-61 and 1961-62) the prices at the fair price shops had to be fixed at a lower level and the resulting extra demand had to be met to keep the rising prices in check in the deficit states, whereas the prices tended to fall simultaneously in the surplus states. Consequently, any sizable buffer stock could not be built [4, p. 4]. The all-India price index, which is an average of selected markets in deficit and surplus states, conceals the regional variations in prices [4, p. 49].

In the absence of zonal restrictions, the variations in the food-grain prices between the surplus and deficit states would have been less marked, so the fixation of lower prices to prevent undue rise in the open market prices would not have been necessary. Under these circumstances, if the price in the fair price shops had been raised to a reasonable level, the prices in the open market would have attained a new equilibrium at a higher level on the one hand, and, on the other, the economy would have absorbed only that quantity of imported cereals

Table 1. Difference between prices at fair price shops and prices in the open market

Year	Bombay (Mahastra)	Bhus (Gujrat)	Patna (Bihar)	Kanpur (U.P.)	Ajmer (Rajasthan)	Ludhiana (Punjab)
			rupees			
1956	15.85	13.70	6.08	1.38	5.11	2.92
1957	27.49	13.70	21.25	3.54	8.12	1.20
1958	29.27	16.42	25.89	10.09	16.04	2.96
1959	39.88	29.04	36.15	8.18	15.20	4.77
1960	38.88	24.07	14.37	7.58	11.32	0.03
1961	33.00	8.83	16.97	−1.58	6.30	−0.74
1962	31.42	13.58	16.07	2.83	3.13	2.02
1963	30.08	15.90	18.83	1.17	1.34	3.72
1964	46.33	15.00	54.08	31.75	12.60	15.18

Source: *Report of the Study Team on Fair Price Shops* [5, p.8]

These figures reveal that, although the difference between the open market prices and those at the fair price shops was insignificant in the surplus states like Punjab, it was very large in the deficit states like Maharastra, Gujrat, and Bihar. The price differentials are largely explained by the zonal restrictions on the movement of food grains between the surplus and

which was equal to the gap between q^dt and q^st at the new equilibrium price, and the building up of stocks would have been facilitated. The Study Team on Fair Price Shops seems to support this reasoning [5, p. 9].

The rise in prices, p^t, in Mann's model would result in decline in q^dt, for q^dt is the function of p^t and y^t. The decline in q^dt could be adjusted with the w^t in the market-clearing equation of Mann's model in the year of import, assuming that I^pt and I^ot remain unchanged. If we use the lags in Mann's model, an increase in the prices in the initial year 0 will result in an increase in domestic production in year 1 and a rise in q^st in year 2. Therefore, the domestic supply will gradually increase and, if the process is continued, a point will be reached at which q^st will eventually balance with q^dt and there will be no need of I^pt and I^ot.

In India, however, there have been physical constraints on the supply of various input factors, and, therefore, an increase in acreage due to an increase in p_t may not necessarily bring about corresponding increase in agricultural production [1, p.13]. But the fact remains that the prices not only may be prevented from falling but actually can be kept at a higher level despite P.L.480 imports through the working of the fair price shops.

UMA KANT SRIVASTAVA
Lucknow University

References

[1] DANTWALA, M. L. "Incentives and Disincentives in Indian Agriculture," *Indian J. Agr. Econ.* 22:1–25, April–June, 1967.

[2] MANN, JITENDAR S., "The Impact of Public Law 480 Imports on Prices and Domestic Supply of Cereals in India," *J. Farm Econ.* 49:131–146, Feb. 1967 (Part I).

[3] RAJ, K. N. "Regional Variations in Foodgrains Prices," *Econ. & Pol. Weekly* 1:49–51, Aug. 20, 1966.

[4] ———, *Indian Economic Growth Performance and Prospects,* Nalanda College, Jan. 1965.

[5] *Report of the Study Team on Fair Price Shops,* Department of Food, Government of India, New Delhi, 1966.

THE IMPACT OF PUBLIC LAW 480 IMPORTS ON PRICES AND DOMESTIC SUPPLY OF CEREALS IN INDIA: REPLY

The study reported in the article under debate [7] was based on all-India yearly aggregated data and had to abstract from the seasonal variations or variations among the regions.

It seems that the commentator has missed the impact of the conclusion that the net contribution of P.L. 480 imports to consumption is always positive. To illustrate, if one pound of cereals added to the supply brings about a decline in domestic supply of 0.2 pounds and a net addition of 0.8 pounds to consumption, how will this "increasingly widen the gap between the demand and domestic supply"? In the absence of P.L. 480 imports, the net addition to availability (from domestic supply) will be only 0.2 pounds. It is only when the decline in domestic supply is greater than the imports under P.L. 480 that the gap

between supply and demand will progressively increase, "defeating the very purpose of food aid." However, the Indian economy is not that pathological yet.

It is a matter of elementary economics that any addition to the supply of a commodity which has a negatively sloping demand curve will depress the price. During the years 1957–1963, the P.L. 480 imports of wheat were over 21 percent of domestic net supply (net of feed, seed, and waste) of wheat; only a miracle could have prevented an impact on the price. The index of wholesale prices of wheat was 83 in 1957 and 69 in 1963. For all cereals, the index was 94 in 1957 and 85 in 1963.

The efficacy of the fair price shops in maintaining the price level of cereals is worth investigating; but the sketchy surmises which have been thrown around are not at all conclusive. Four points may, however, be noted. First, the price of wheat at the fair price shops has remained fixed for several years (how this price is determined, nobody knows), and this lack of variation reduces the usefulness of this price as a variable in any statistical analysis. Second, if the fair price shops are considered relief agencies, why are they as active in surplus areas as in deficit areas? Third, as far as holding the price line is concerned, it has been pointed out that "the Government with the help of P.L. 480 imports has tried to hold the price of wheat at an artificially low level" [9, p. 200]. Fourth, it has been suggested that the wheat issued at the fair price shops is considered to be inferior to the wheat available in the open market [9, p. 89]. If this is true, then the analysis needs to be extended to separate the demand in the free market from that at the fair price shops.

Given a fall in price, there is always a decline in the quantity supplied, except in the extreme case of a supply function with zero elasticity. In the context of the debate on P.L. 480, the sluggishness of the Indian economy and the lack of price responsiveness were first suggested by Khatkhate [4] and Olson [8]. However, recent empirical studies have shown that there is a positive price response of agricultural production in the developing countries [1, 2, 3, 6]. The implications of the positive slope of the supply curve for agricultural policy in India have recently been examined by Khusro [5].

However, the supply function is not very elastic and price support alone cannot solve the problem of low supplies. Improvements in the technique of production are needed to bring about a shift in the supply curve to the right.

The solution to Indian agricultural stagnation is a technological revolution. Till recently, the P.L. 480 operations were guided by the idea of surplus disposal. A commodity for shipment under P.L. 480 had to be in surplus: that is, at the time of export or donation, its supply had to exceed domestic requirements, adequate carry-over, and anticipated exports for dollars, as determined by the Secretary of Agriculture. Agricultural economic development was not considered as one of the major objectives of the program. However, under the new Food for Peace Act of 1966, effective January 1, 1967, the philosophy of "surplus" has been abandoned in programming food aid. In order to help developing countries, shipments of agricultural commodities which are "available" will be made. The empha-

sis now is on self-help by the recipient countries, which must conscientiously provide more and more of their own food requirements from their own efforts and their own resources. An imaginative price policy combined with measures to increase fertilizer production, improve soil and water management, provide agricultural credit, and control floods can bring about the desired increase in the domestic supply of food in India and eliminate the need for P.L. 480 imports in the long run.

JITENDAR S. MANN
University of Minnesota

References

[1] BATEMAN, MERRILL J., "Aggregate and Regional Supply Functions for Ghanian Cocoa, 1946–1962," *J. Farm Econ.* 47:384–401, May 1965.
[2] BEHRMAN, JERE R., "Supply Response in Underdeveloped Agriculture: A Case Study of the Four Major Annual Crops in Thailand, 1937–63," unpublished Ph.D. thesis, Massachusetts Institute of Technology, 1966.
[3] DEAN, EDWIN R., "Economic Analysis and African Responses to Prices," *J. Farm Econ.* 47:402–409, May 1965.
[4] KHATKHATE, DEENA R., "Some Notes on the Real Effects of Foreign Surplus Disposal in Underdeveloped Economies," *Quart. J. Econ.* 76:186–196, May 1962.
[5] KHUSRO, ALI M., "The Pricing of Food in India," *Quart. J. Econ.* 81:271–285, May 1967.
[6] MANGAHAS, MAHAR, AIDA E. RECTO, AND V. W. RUTTAN, "Market Relationships for Rice and Corn in the Philippines," *J. Farm Econ.* 48:685–703, Aug. 1966.
[7] MANN, JITENDAR S., "The Impact of Public Law 480 Imports on Prices and Domestic Supply of Cereals in India," *J. Farm Econ.* 49:131–146, Feb. 1967 (Part I).
[8] OLSON, R. O., "Discussion: Impact and Implications of Foreign Surplus Disposal on Underdeveloped Economies," *J. Farm Econ.* 42:1042–45, Dec. 1960.
[9] RATH, NILKANTH, AND V. S. PATVARDHAN, *Impact of Assistance Under P. L. 480 on Indian Economy*, New York, Asia Publishing House, 1967.

ANALYTICAL ISSUES IN DEMAND ANALYSIS FOR OUTDOOR RECREATION: COMMENT

The Stoevener–Brown (henceforth S–B) article in a recent issue of this journal [5] (*a*) corrects a computational error which I made in a 1966 article [4], (*b*) dramatically confirms the thesis of that article, and (*c*) raises interesting questions of estimation and computation in correcting a demand curve. This article and Professor Gardner's discussion [3] also (*d*) raise some important questions in the theory of welfare economics.

a) In the Appendix to my paper, I used a regression equation taken from the excellent Oregon Steelhead Salmon study to "illustrate" the "influence" of income on user-days taken. I failed to note that the variables were coded and thus my numbers were wrong. This error is corrected in S–B's computations of Figure 2 and related data. In terms of "influence"—that is, given changes in income affecting given changes in prices—the S–B computations and mine roughly correspond.

b) My thesis was that, if differences in income are not corrected for, received evaluation procedures bias project selection toward the comparatively well off. This thesis is dramatically con-

firmed by the S–B benefit computations [5, p. 1302] and decisively refutes Gardner's "straw man."

c) I suggested that the demand curve is not equal to the marginal utility curve because of the diminishing marginal utility of income [2]. I further hypothesized that a demand curve "corrected" for income distribution would be "flatter" than the original demand curve. It seems that this is the only technical point of contention between S–B and myself and therefore deserves some discussion.

If tastes are randomly distributed with respect to income, and if one finds user-days demanded to be positively correlated with income, then this fact may be taken as at least circumstantial evidence of the diminishing marginal utility of income. It is natural to ask what the demand curve would look like *if* all consumers had the same income (and, hence, under assumptions of equal tastes, the same marginal utility of income). It is, unfortunately, easier to ask this question than to answer it statistically—that is why I carefully hedged my comments on the corrected demand curve and its statistical definition. The one hypothesis which I ventured was that a demand curve, properly corrected for, would be *flatter* than the original (or "statistical") demand curve.

The reasoning behind this hypothesis was elementary: Persons willing to pay the highest price for a unit of the good x are, partially, those with the highest incomes; those unwilling to pay any but the lowest prices are, partially, those with the lowest incomes. Thus, if the highest had less, and the lowest more, income, quantity of use at the highest price would be less, and at the lowest price, more, than originally.

Let us show this graphically. Assume the potential consumers of x are divided into three equal population groups, A, B, and C. A's income is one-third of C's, B's income is two-thirds of C's, and tastes are identical. Then we may draw Figure 1, in which the point Q_x' expresses the assumption about tastes (that at zero costs, all groups consume the same amounts)[1]; SD is the statistical demand curve that one would obtain by summing the demand curves A, B, and C; and CD is the "corrected" demand curve obtained by summing the demand curve of group B three times. Following this procedure, we can readily see that CD is "flatter" than SD.

Now, to take another tack, assume that through ordinary multiple regression analysis one obtained the logarithmic regression equation (in simplified form):

$$(1)\quad SD = QD_x = A - b_1P_x + b_2Y$$

where

QD_x is the quantity of x demanded,

P_x is the price of x, and

Y is the income of consumers.

Now substitute $\bar{Y}$ (a *given* income) for Y (*any* $\bar{Y}$ in the set of Y)[2] to define CD (equation 2).

$$(2)\quad CD = QD_x' = A - b_1P_x + b_2\bar{Y}.$$

If we subtract as follows,

$$QD_x - QD_x' = b_2(Y - \bar{Y}),$$

[1] This may be a source of the difference between S–B and myself—it is difficult to express this assumption statistically, given the usual estimation procedures.

[2] The selection of $\bar{Y}$ is a problem which cannot be solved in this context, since the only practical reason for "correcting" is to compare alternative projects. It certainly would not be the *average income* of the particular project under consideration, although it may, for example, be the average income of the set of *all* projects under consideration. In the *theoretical* figures in my original paper, I set $\bar{Y}$ rather high, assuming a project with comparatively low-income patrons.

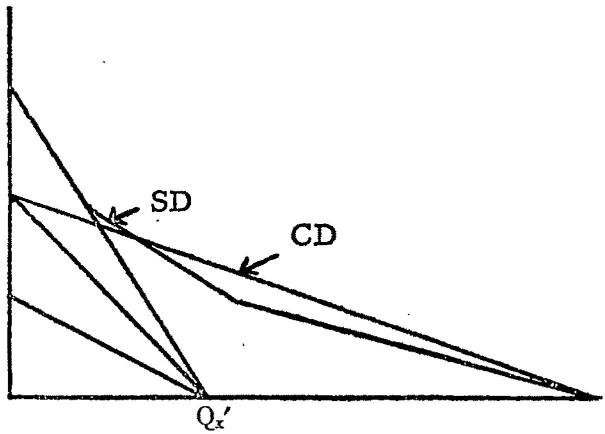

Figure 1. Two aggregate demand curves

it is clear that, at *any given price*,

if $Y=\bar{Y}$, then $QD_x-QD_x'=0$,

if $Y<\bar{Y}$, then $QD_x-QD_x'<0$, and

if $Y>\bar{Y}$, then $QD_x-QD_x'>0$.

Again, the relationships are as hypothesized: *CD* is "flatter" than *SD*.

Now, I am not willing to declare that the methodology followed above, particularly given current estimation procedures, is the best way to correct a statistical demand curve. As I originally noted, such correction would require "extended mathematical and statistical investigation." The S–B "correction" of Figure 1 fully confirms the need for caution here. Not only was the difference which S–B found between *SD* and *CD* an insignificant one, but also such difference as they did find directly contradicted the strictly tautological relationships between QD_x and QD_x' found above. I cannot pretend to know how these results came about; I do, however, know that econometric methodology teaches us to be suspicious of statistical results which contradict the qualitative properties of economic models. Until S–B can show how two *different* equations (1 and 2) can result in the same *curve*, I remain suspicious.

The "greatly exaggerated" charge, if it refers to my main thesis or to the Appendix is, therefore, refuted by S–B's own evidence. If it refers to my corrected demand curve, I note that I made no quantitative statement—only the qualitative "flatter" hypothesis. I concede, however, that I thought (and still think) that it would make a significant difference. The amount of difference would be a function of several factors: (*a*) the choice of $\bar{Y}$, (*b*) the extent and variance of income distribution (obviously less among subzones than among families), (*c*) the differential price elasticities of income groups, and others. I shall, until I am proved wrong, stick to both the "flatter" and the "significantly different" hypotheses.

d) I should now like to address, however briefly, more general issues raised by S–B and Gardner.

(1) It is a fundamental proposition in welfare theory, that there are any number of "optimal" states of an economy corresponding to any number of value judgments on distribution. Thus, economic "analysis" and such words as

"efficiency" and "welfare" are essentially subjective.

S–B and Gardner imply, on the other hand, that one can determine an optimal distribution without reference to value judgments—that it is somehow improper to criticize economic "analysis" on the basis of "one's personal biases." Indeed, S–B attempt to divorce "analysis" from "policy" [5, p. 4], insisting all the while [p. 5] that analysis must be "relevant to decision makers." S–B and Gardner even imply that if one accepts the existing state of distribution one is somehow being objective, whereas if one questions the status quo in this respect one is passing "value judgments." Clearly, if one "accepts" the status quo, one is saying that it is *good*. Such biases can stem only from a misapprehension of welfare theory.

(2) Although it may be true that, if one wishes to redistribute income, general taxation and lump-sum payments are best, it does not follow that, if one merely wants to neutralize the exclusion principle with respect to a few select goods (for example, medical care, education, outdoor recreation), these general policies are best. They are, on the contrary, grossly inefficient compared to selective subsidization.

(3) I agree with Bator [1, Chap. 6] (and, I believe, with most welfare theorists) that received welfare theory is not a sufficient basis for even an economic theory of the state. Certainly, the case for subsidizing outdoor recreation (even in the narrow confines of welfare theory) can be made on grounds other than that it must somehow "pay for itself" in increased productivity of the consumer.

(4) It is an error to associate my article with the quality-vs.-quantity argument or other views of the anti-economist establishment. While I have my own views on this subject, the article is an exercise in pure welfare theory and can be considered only in those terms.

(5) Lastly, while I share Professor Gardner's fear of bureaucratic sloth and ineptitude in the management of economic affairs, I fear even more the opposite extreme—the putrid environment and vicious inhumanity of laissez-faire capitalism.

On these issues, we can all be "hawkish."

David William Seckler
Colorado State University

References

[1] BATOR, FRANCIS M., *The Question of Government Spending*, New York, Harper and Bros., 1960.

[2] BUTCHER, WALTER R., "Willingness to Pay, Consumer's Surplus, and the Constant Marginal Utility of Income Assumption," paper given at the Western Farm Economics Association meeting, July 1967.

[3] GARDNER, DELWORTH B., "Discussion: Analytical Issues in Demand Analysis for Outdoor Recreation," *J. Farm Econ.* 50: 1304–06, Dec. 1967.

[4] SECKLER, DAVID W., "On the Uses and Abuses of Economic Science in Evaluating Public Outdoor Recreation," *Land Econ.* 42:485–494, Nov. 1966.

[5] STOEVENER, HERBERT H., AND WILLIAM G. BROWN, "Analytical Issues in Demand Analysis for Outdoor Recreation," *J. Farm Econ.* 50: 1295–1304, Dec. 1967.

ANALYTICAL ISSUES IN DEMAND ANALYSIS FOR OUTDOOR RECREATION: REPLY

Professor Seckler comments on an article in the December issue of this journal [3] in which we referred to work published by him earlier [2]. His comments indicate that we apparently did not make our intentions clear. We shall refer only to points *c* and *d* in Seckler's comment, since these appear to be the only areas of misunderstanding between him and us.

We attempted to demonstrate that the demand function fitted to the Oregon salmon–steelhead data could not be "corrected" for income distribution as Seckler suggests. The possibility of making such a correction for any function appears to depend upon its algebraic form. For the demand equations employed in the Oregon salmon–steelhead (S–S) study, averaging of income among all the subzones had no effect upon the slope of the demand curve, since increases in S–S days taken by low-income subzones after averaging incomes were offset by decreases in S–S days taken by the originally higher-income zones. In fact, the "corrected" demand curve in Figure 1 of our paper [3] would have been identical with the original except for small deviations caused by setting estimated S–S days by subzones equal to zero whenever estimated S–S days for those subzones became negative.

For the more general case, let us first consider a linear demand equation, following Seckler's notation:

(1) $SD = QD_x = A - b_1P_x + b_2Y$, where

QD_x is the quantity of x demanded,
P_x is the price of x, and
Y is the income of consumers.

Note that a given increase in income for an initial Y value merely enters as a constant and shifts the demand curve away from the origin but does not change the slope of the price–quantity line. Thus, an averaging of incomes between different income subzones could not affect the slope of the above simple type of demand equation. Seckler shows this algebraically following equation (2) of his comment. However, we do not understand how this leads him to conclude that "*CD* is 'flatter' than *SD*."

Next, if the preceding equation (1) had been fitted in logarithms, then the demand function would no longer have been linear in real numbers and it is hard to know precisely what is meant by Seckler's term "flatter." At any rate, the general shape of this algebraic form of demand curve remains unaltered if one uses average income over all subzones rather than the original income distribution. In this case, the original demand curve is simply multiplied by some constant which is greater or less than one, depending upon the nature of the income distribution and the estimated regression coefficients.

Although the general form of the preceding demand functions was not altered (and, therefore, not "flattened," if we understand what Seckler means by the term), it is possible to construct an algebraic equation which will approximate the situation pre-

sented in Seckler's Figure 1. For example, suppose that

$$(2) \qquad Q = 1.0 - \tfrac{2}{3}(P/I).$$

If income of C is denoted by $I_c = 1.0$, then the equation for C would be

$$Q_c = 1.0 - \tfrac{2}{3}P.$$

If income of A is ⅓ that of C (that is, if $I_a = \tfrac{1}{3}$), then

$$Q_a = 1.0 - 2P.$$

Similarly, for $I_b = \tfrac{2}{3}$,

$$Q_b = 1.0 - P.$$

The type of function indicated by equation (2) seems to be one which produces the desired Seckler "flattening" effect. We have not observed the use of this type of function in recreational demand studies. However, perhaps this type of function should be tried and results compared with those of other models. In fact, there are many such methodological problems in fitting recreational demand curves which need attention. One poor procedure employed in the Oregon salmon-steelhead study was the equal allocation of population to each subzone of a given main zone [1, p. 43]. Subzones should have been given population numbers corresponding as closely as possible to the number of people in the main zone actually falling within these income classes.

To reiterate, it is possible to have statistical demand curves of algebraic forms which, when "corrected" for income distribution, can be "flatter" than the original. However, this is not possible for the algebraic forms of functions commonly employed in demand analysis for outdoor recreation which are the subject of this exchange. Perhaps the more fundamental question relates to the appropriateness of the functional forms heretofore used in empirical work in this area. We would gladly agree with the suggestion that the solution to this problem has yet to be determined.

We believe that careful study of our paper will reveal no attempt on our part to associate Professor Seckler's work with "views of the anti-economist establishment." Among a number of points which we tried to make, there were two for which we used his article as an illustration. Both are in the realm of the professional economist. The major one of these concerned the interpretation of value estimates from statistical demand functions for outdoor recreation. This item was discussed above. The other one related to the use of price as a rationing device for outdoor recreational services. We questioned the consistency between subsidizing those outdoor recreational services which are mainly enjoyed by upper-income groups and other economic policies which might give us some indication of national objectives with respect to income distribution. We questioned the efficacy of certain outdoor recreational policies as instruments for changing the income distribution. Does such questioning imply a misapprehension of welfare theory commensurate with saying that an analysis conducted within the framework of a given income distribution is *wertfrei*?

HERBERT H. STOEVENER AND
WILLIAM G. BROWN
Oregon State University

References

[1] BROWN, W. G., A. SINGH, AND E. N. CASTLE, *An Economic Evaluation of the Oregon Salmon and Steelhead Sport Fishery*, Oregon Agr. Exp. Sta. Bul. 78, Sept. 1964.

[2] SECKLER, DAVID W., "On the Uses and Abuses of Economic Science in the Evaluation of Outdoor Recreation," *Land Econ.* 42:485–494, Nov. 1966.
[3] STOEVENER, HERBERT H., AND WILLIAM G. BROWN, "Analytical Issues in Demand Analysis for Outdoor Recreation," *J. Farm Econ.* 49:1295–1304, Dec. 1967.

THE STERN TEST OF OBJECTIVITY FOR THE USEFUL SCIENCE OF AGRICULTURAL ECONOMICS: COMMENT

In his plea for objectivity in agricultural economics [1], Harold F. Breimyer has said many things worth saying, but by refusing so fastidiously to rake any "muck"[1] [1, p. 340], he has himself tried to avoid controversy in the same way that he deplores in others [1, p. 347]. The net effect of his remarks is to praise our profession with faint damns, to pave over such "muck" as may really be there, and to refurbish the only slightly dishevelled cause of antidisestablishmentarianism.[2]

Objectivity is certainly something to be striven for. But emphasizing it, as Breimyer does, will not get us very far, because it is seldom if ever attainable in any real sense. That the literature on the problem of objectivity "is sparse" [1, p. 340] should surprise no one. Economists should realize that they are poor judges of their own objectivity. Some do, and have even set forth their own predilections, insofar as they were aware of them, as a warning to readers.

Books have been written to demonstrate that economic theory is, and even *should* be, a product of the times and the mores. For example, Leo Rogin wrote: "There can be no question of a uniquely correct theory. Different practical and normative perspectives call for different selection and organization of facts" [8, p. xv]. That Rogin believed he had discovered the "objective meaning of economic theory" [8, p. 13] is simply added evidence that objectivity is a will-o'-the-wisp.

Most people, including most agricultural economists, pretend to an objectivity they do not possess. Only those aware of, and perhaps troubled by, this problem are likely to take an attitudinal stance similar to Rogin's. This includes Don Paarlberg, who, as I earlier pointed out in this journal, "redefined 'objective research' to mean research directed toward a particular objective" [5, p. 462].

In short, objectivity is a myth, no more definable than truth. And "when two persons possessed of the same technical capacity, observing the same data, and testing the same hypothesis arrive at essentially identical conclu-

[1] In the early years of this century, so-called "muckrakers" performed a real service to the American people by uncovering and publicizing many of the hidden ills of society. But the service is now largely forgotten, and all that remains is the unsavory epithet coined by Theodore Roosevelt.

[2] This word refers to one side of a vigorous nineteenth-century dispute concerning the proposed disestablishment of the Church of England. In relation to agricultural economics, the word is here revived to describe that attitude of mind which automatically rejects all criticism [4, p. 847] of the "establishment." In other words, antidisestablishmentarianism in agricultural economics means *not* rocking the boat, *not* making waves, and *not* approving of those who do. It is probably still the majority view.

sions" [1, p. 340], what has been observed is an accident, nothing more. One man's objectivity may easily be another's "objectivism," à la Ayn Rand [6, p. 92]. Controversy *must not* be avoided by taking the "high ground" of pretended objectivity.

But if Breimyer's "chief message" is thus misleading, what should the message be? It should be that agricultural economics needs more penetrating, original, diverse, and, yes, *controversial* discussions of its problems. As I contended earlier, "Because so many aspects of agricultural economics are not truly scientific, we must not only defend but actually foster the right of dissent. Active disputation, in other words, continuously encouraged, is our only defense against the ultimate charge of charlatanry" [4, p. 847].

Objectivity is a poor weapon indeed against entrenched error, which is more common than Breimyer admits. And the establishment, though not monolithic, is all-pervasive and ever-adaptable. As to Breimyer's appraisal of the "performance record" [1, p. 344], I agree that, insofar as evidence is available, performance has been good in his first category of "counsel to the firm." I also agree (1) with his assertion that the chief problem is in matters of public policy, and (2) with his organizational prescription that policy and program analysis and appraisal should be placed "in the hands of specialists in units separate from, but next door to, the operating staff" [1, pp. 346–347]. As I said earlier, policy and program "research is legitimate, but it is best left primarily to action agencies, for otherwise agricultural economics becomes the transferable handmaiden of the political party in power" [5, p. 463].

But I cannot concur in his "good-conduct medal" to the people developing methods and techniques. In almost all cases, these are now the *same* people who help analyze and appraise public policy; and in a few cases, at least, they may justly be accused of tailoring their views to their own opportunism—and of adapting techniques to current requirements of the establishment.

Kirkendall has discussed [7, p. 6] the danger that social scientists in government may become "mere servants of power," abandoning "the wider obligations of the intellectual who is a servant of his own mind." Although some "frustrations" were experienced under Franklin Roosevelt, the social scientists did *not* conclude "that their responsibilities were to power alone." For agricultural economists, this came later. The discipline has *already* capitulated; and, Breimyer to the contrary [1, p. 341] notwithstanding, capitulation may have been necessary in order to *retain* public support.

The establishment "puts down" anyone with the temerity to buck it. "In economic matters, there is no advantage and, on the whole, some peril in being first with a rational point of view" [3, p. xi].[3] This is why dissent is not only a right but a duty. "It cannot be too often repeated that the justification and the purpose of freedom of speech is not to indulge those who want to speak their minds. It is to prevent error and discover truth. There may be other ways of detecting

[3] The aphorism, "One can do a lot of good in this world if he cares not who gets the credit," was obviously not coined by an experienced do-gooder. It should read, "One can do a lot of good in this world if he can withstand the inevitable opprobrium and ostracism."

error and discovering truth than that of free discussion, but so far we have not found them" [2, p.23].

Dissent couched in the guise of objectivity is no dissent at all. Dissent is inevitably subjective. But for detecting error and discovering truth, freewheeling and countervailing subjectivity is better than pretended objectivity. If "muck" is present, it *should* be raked. Only thus is sufficient stench released to induce a clean-up movement.

ERNEST W. GROVE
Agricultural Stabilization and Conservation Service, USDA

References

[1] BREIMYER, HAROLD F., "The Stern Test of Objectivity for the Useful Science of Agricultural Economics," *J. Farm Econ.* 49:339–350, May 1967.

[2] COMMAGER, HENRY STEELE, "The Problem of Dissent," *Saturday Rev.* 48 (51):21–23, 81, Dec. 18, 1965.

[3] GALBRAITH, JOHN KENNETH, "Foreword" to *The Critical Decade: An Economic Policy for America and the Free World,* by Henry S. Reuss, New York, McGraw-Hill Book Company, 1964, pp. xi-xii.

[4] GROVE, ERNEST W., "Basic Research in a Quasi Science," *J. Farm Econ.* 47:846–848, Aug. 1965.

[5] ———, "Mission Oriented Research," *J. Farm Econ.* 47:462–463, May 1965.

[6] HAMBLIN, DORA JANE, "The Cult of Angry Ayn Rand," *Life* 62(14):92–102, April 7, 1967.

[7] KIRKENDALL, RICHARD S., *Social Scientists and Farm Politics in the Age of Roosevelt,* Columbia, University of Missouri Press, 1966.

[8] ROGIN, LEO, *The Meaning and Validity of Economic Theory: A Historical Approach,* New York, Harper & Bros., 1956.

THE STERN TEST OF OBJECTIVITY FOR THE USEFUL SCIENCE OF AGRICULTURAL ECONOMICS: REPLY

Meaning exists apart from the capacity of fallible human beings to perceive it. Objectivity as an idea has firm, hard meaning, as does truth. Neither is a myth, and neither is indefinable, as an idea. The problem arises in knowing the best path for pursuit, and how to recognize the degree of attainment or nonattainment.

Nor is the idea of objectivity to be counterpoised against the exercise of disputation. They are not of the same logical category. Further, although checkreining disputation may help to extend the life of entrenched error, allowing disputation does not guarantee absence of error. Sometimes debate yields only noise.

It is always tempting to suggest that because economics as a social science lacks the neat orderliness of the physical sciences there is less call for rigor in its practice. If anything, not less rigor is required, but more.

I too studied under the estimable Leo Rogin. The wisdom of his teachings stands despite Grove's drawing a questionable conclusion from them.

With this major qualification, I welcome Grove's corroboration of some of my observations about the state of affairs in agricultural economics—observations which are hardly antidisestablishmentarian.

HAROLD F. BREIMYER
University of Missouri

"REALIZED" FARM INCOME: AN OUTMODED CONCEPT? REPLY

If Mr. Grove [1] had read beyond the first two sentences of a newspaper extract from a popular article of mine [2], he would have realized that, far from detecting a difference between Agriculture and Commerce Department estimates of farm income, I treated them as virtually identical. The point of my article was not whether there are different estimates of farm income, but that farmers in Texas reported a net loss of $60 million dollars when the official estimates indicated a net income of over $800 million dollars. While frequently confused, especially in matters involving the United States Department of Agriculture, I am well aware that the Commerce Department figures are derived from the Agriculture Department estimates. It would have been interesting to see how Mr. Grove explained the tax reporting problem I was concerned with, but in any case we should all be grateful for his effort to clear some deadwood from the jungle of agricultural statistics.

HENDRIK S. HOUTHAKKER
Harvard University

References

[1] GROVE, ERNEST W., "'Realized' Farm Income: An Outmoded Concept?" *J. Farm Econ.* 49:795–805, Nov. 1967.

[2] HOUTHAKKER, HENDRIK S., "The Great Farm Tax Mystery," *Challenge, The Magazine of Economic Affairs*, Jan. 1967.

PROSPECTS FOR POPULATION CONTROL: REPLY

The comments of Dr. Karol Krotki concerning my paper on population control [Donald J. Bogue, "Prospects for Population Control," and discussion by Karol Krotki, *J. Farm Econ.* 49:1094–1105, Dec. 1967] represent the thinking of a majority of today's demographers, and merit the careful reading of all who read my paper. Although I am firmly convinced that this more pessimistic view is dead wrong and that dramatic strides are being made to resolve the world's population problem, I am vulnerable to his charge that as one of the participants in these programs my judgment may be impaired by ego-involvement and wish-fulfillment. May I counsel readers to relax and await the results of the 1980 census. If Dr. Krotki is correct, population in the developing nations will be growing at very nearly the same rate during the 1970–1980 decade as it is now. If my thesis is correct, there should be a dramatic drop in the rate of population growth in comparison with the 1960–1970 decade.

May we all be present to note whether the citizenry of the developing nations is capable of "facing up soberly to its [demographic] future"! In his final paragraph, Dr. Krotki clearly states his belief that the great masses of Asia, Africa, and Latin America lack this ability. I firmly believe that they possess it today, and are acting on it.

DONALD J. BOGUE
University of Chicago

ON THE ECONOMICS OF PRODUCE GRADING*

David Price is to be commended for his recent article on "Discarding Low Quality Produce with an Elastic Demand" [7]. The economics of fruit and vegetable grading have hitherto received far too little attention. I should like to supplement his fine technical analysis with a few more general comments.

Let me start with the question of why standards were established. I suggest that little if any economic analysis has been used in establishing existing produce grades, except possibly for some associated with marketing orders. Rather, the regulations were more a practical question of providing a standard of identity for trading purposes at the wholesale level. In some cases there may have been interest in keeping produce of particularly poor quality—that which is damaged, spoiled, etc.—off the market. As Price suggests, some knowledge of economics might have discouraged interest in grades for certain products.

The actual rationale behind grades may seem unimportant, in terms of the problem Price poses, but it is not. For if quality is to be the ploy, and the products in question are to be consumed directly or in relatively unchanged form, consumer preferences must ultimately be taken into consideration. The really important problem for produce, then, is to define a set of objective factors—factors that can readily be measured—that are consistent with consumers' conceptions of quality.[1]

Perhaps this can be most easily and clearly illustrated by the case of applesauce—not strictly produce, but only one step removed. Several years ago, my brother reported a study which indicated that consumers in New York State, when presented with applesauce graded according to federal standards, preferred the substandard sauce over that graded No. 1 or No. 2 [4]. Part of the reason is that they liked a thin sauce, which is severely penalized in U.S. grades. Other studies have provided support for the proposition that consumers and others do not necessarily agree with the USDA method of weighting sauce grade factors [3, pp. 23–25]. Since the grades were not set up for consumer use, but to "serve as a convenient basis for sales, for establishing quality control programs, and for determining loan values" [9], this result is not entirely unexpected. But if consumer-oriented grades were to be established, considerable testing would be necessary to determine actual preferences. This process could be complicated by possible geographic variations in tastes [1, p. 65, Table 60].

If an appropriate grade were established—one that consumers would pay for—what would be the effects at the retail and farm levels? This is not always easy to say. Although it is well known that price elasticity of demand

* I have benefited from the helpful comments of Fred Waugh and John Porter.

[1] This would not be such an important consideration for many agricultural products, such as grains, cotton, and tobacco, which are sold to manufacturers and substantially transformed. In this case, the wants and needs of the processors can be quite different from those of the consumers.

at the farm level is generally less than at retail, it is less widely recognized that demand for some fruits is elastic at retail and inelastic at the farm[2] [10, pp. 81–129]. (The commodities which Dr. Price studied did not fall into this category; both farm and retail demand were elastic.) In these cases, programs which are economically logical on the basis of an inelastic demand at the farm level may be considerably less appropriate because of an elastic demand at retail: reduction of supplies might favor the farmer in his price relationship with wholesalers and processors but would not be equally desirable at retail. Although this disparity might be overlooked in the short run, it could create difficulties in the longer run.[3]

A more mundane problem centers about costs and returns. Where produce is already being extensively graded, the cost of adjusting existing grades is small. But if grading is to be introduced for a product which has not previously been sorted, then such problems as the costs in terms of equipment and the changing of farmers' attitudes become more substantial. As Kross has pointed out, many of the early programs to get farmers to grade potatoes were introduced without showing the cost-and-return relationship. Since many farmers doubted whether there would be sufficient additional returns, they were slow to take up grading [6]. In any case, costs can be offset to some extent if a low-income or processing market can be found for the culls.

A program to use grades in conformity with economic reasoning, therefore, might have to face three important issues: (1) the development of objective standards that are in line with consumer proclivities, (2) a study of the effects at the farm and retail levels, especially in the cases where farm demand is inelastic and retail demand is elastic, and (3) an evaluation of costs and returns where grading is a new activity. Other related economic factors would also have to be considered.[4] Then too, the effect of possibly higher prices on low-income groups should be weighed. While the use of standards to maximize farm income for produce is a most engaging idea, it may be a more complex matter than is at first realized.

DANA G. DALRYMPLE
International Agricultural Development Service, USDA

[2] This example is at the industry level. As Price notes, demand may be more elastic for the individual firm than for the industry as a whole.

[3] I have discussed this problem, in terms of diversion programs for apples, in some detail elsewhere [2, pp. 310–327].

[4] These include such matters as competitive relationships with other products and regions and the influence of improved price on production. For further insight into these matters, in the context of marketing orders and agreements, see Farrell [5, esp. pp. 346–353] and Smith [8].

References

[1] CLAYTON, L. YVONNE, *Homemaker's Use of and Opinions About Selected Fruit and Fruit Products*, USDA SRS, MRR 765, Aug. 1966.

[2] DALRYMPLE, DANA G., "Economic Aspects of Apple Marketing in the United States," Ph.D. thesis, Michigan State University, 1962. (Pages 310–327 reprinted as "Bargaining and Controlled Distribution: The Case of Apples," in *Studies on the Economic Aspects of Fruit and Vegetable Bargaining*, USDA FES, Feb. 1963, pp. 20–28.)

[3] ——, *Recent Developments in the Production and Marketing of Apple Sauce and Slices,* USDA FES, July 1965.

[4] DALRYMPLE, DOUGLAS J., "A Study of Consumer Preference for Applesauce Using the Two-Visit Interview Technique," *J. Farm Econ.* 43:691–697, Aug. 1961.

[5] [FARRELL, KENNETH R.], "Marketing Orders and Agreements in the U.S. Fruit and Vegetable Industries," in *Organization and Competition in the Fruit and Vegetable Industry,* National Commission on Food Marketing, June 1966, pp. 287–357.

[6] KROSS, JOHN I., "At What Grade Does It Pay to Sell Potatoes?" *J. Farm Econ.* 34:387–391, Aug. 1952.

[7] PRICE, DAVID W., "Discarding Low Quality Produce with an Elastic Demand," *J. Farm Econ.* 49:622–632, Aug. 1967.

[8] SMITH, ROY J., "The Lemon Prorate in the Long Run," *J. Pol. Econ.* 69:573–586, Dec. 1961.

[9] U. S. Department of Agriculture, *United States Standards for Grades of Canned Applesauce,* AMS, effective Sept. 18, 1950.

[10] Western Extension Marketing Committee, *A Handbook on the Elasticity of Demand for Agricultural Products in the United States,* Colorado State University, July 1967.

Reviews are listed alphabetically by authors.

Reviews

Abbott, J. C., and H. C. Creupelandt, *Agricultural Marketing Boards, Their Establishment and Operation*, Rome, Italy, Food and Agriculture Organization of the United Nations, 1966, xii + 236 pp. ($3.50)

This book has been written as if it were designed primarily to be a handbook on marketing boards for use in developing countries. The stated purpose of the authors is "to provide practical advice on the conditions and goals for which a marketing board or similar organization is a useful mechanism, and on how it can be operated successfully" [p. 1].

The central theme is a discussion of the conditions of usefulness, functions, powers and limitations, responsibilities, establishment and directorate, operating methods, staff, and capital requirements of various types of marketing boards. It logically falls into three main areas: first, in the introduction, a general discussion of marketing boards, their objectives, their growth as an approach to solve problems of producers, and some factors, such as adequate management, necessary for successful operation; second, in the main body of the text, chapters 1 through 6, a detailed discussion of each type of marketing board; and third, in the concluding chapter, a consideration of suitability of board types, effectiveness, and relationship to governments.

The authors have delineated six main types of boards. The simplest (type 1) is one set up for advisory and promotional purposes, with duties limited to market research and sales promotion. Regulatory boards (type 2), the next simplest, develop and apply uniform quality standards to export produce. Boards designed to stabilize produce prices by quantity regulations or price fixing are considered type 3. Type 4 boards are boards stabilizing domestic prices for both producers and consumers by entering marketing channels as an additional competing firm. Boards having trading monopoly powers are types 5 (export) and 6 (domestic). In ascending order, each type of board interferes more with existing market structures and demands more sophisticated management and di-

rectorate and more governmental support. However, cumbersome procedures and/or unstable governmental units, a lack of adequate personnel in developing countries, and poorly functioning market structures are the bases upon which the authors justify the development of marketing boards.

This book is not easily read for a couple of reasons. In the early chapters there is a tremendous amount of duplication and repetition. Later chapters refer, under major headings, to previous chapters: for example, on page 162, "See boards types 4 and 5" under "Establishment and directorate." It would have been most beneficial if more careful attention had been given to defining terms the first time they were used; *c. i. f.*, for example, which was used as early as page 59, was finally defined as "cost, insurance, and freight" on page 134. The addition of a glossary might have been helpful. Also, I can find no justification for inconsistency between table headings and tables as in Table 9, page 97. To use this volume as a handbook, the reader may desire to read the introduction, the chapter on the relevant type of board, and the conclusions, and to omit all the rest.

Despite these minor criticisms, this book is a worthy contribution to the literature on agricultural marketing, especially for its conclusions, which, having been presented before, were not surprising but still need repeating. The ultimate effectiveness of marketing boards is largely a function of the caliber of management and the directorate.

WALLACE A. REHBERG
Washington State University

Butani, D. H., and Pritam Singh, eds., *Economic Development, Issues and Policies*, Bombay, Vora and Company, 1966, xvi + 293 pp. (Rs. 20.00)

This is a book on economic development with the main emphasis on India. It consists of 21 chapters or essays written by different authors and was published as a souvenir volume in honor of Dr. P. S. Lokanathan on his seventy-second birthday. Dr. Lokanathan is an Indian economist and was the first director of the United Nations Economic Commission for Asia and the Far East (ECAFE); and at the time of publication he was director of the Economic Research Council of India.

The various essays in this book deal with such topics as the following: the cause and solution of poverty; optimum population; packages of the factors of production; balanced and unbalanced growth; the economist's role in development; the economic practitioner; applied industrial economics; interdisciplinary work of the engineer, the statistician, and the economist; economic cooperation in Asia; productivity in Asia; productivity in India; planning and productivity in agriculture; Japan's trade with developing countries; the Mekong project; saving in India; the growth of the public sector; private enterprise in India; changes in distribution of income and levels of living in India; the role of entrepreneurship; Nehru's foreign policy; and the role of economic journalism.

Two of the chapters in this book are based on household surveys made in

India in 1960, 1962, and 1964. However, most of the essays are hypothetical and theoretical, but with an earnest attempt to be practical about problems of development.

Considerable space is devoted to productivity, but the book falls short of dealing with this subject at the local, micro, and practical level.

Factors and combinations of factors making for economic development are discussed in various chapters. Eugene Stahley in the first chapter discusses the multiplier or synergistic effect of combinations of factors. This is a stimulating introduction to an interesting concept that needs much more documentation. Gunnar Myrdal in Chapter 4 is critical of attempts at models of development in that they probably are not realistic and dynamic in setting up the right questions.

Not enough emphasis is given to such factors in development as basic education, training of leaders, infrastructure, water and irrigation, agricultural credit, and marketing.

The chapters on the public sector and on the private sector of the Indian economy by R. J. Chelliah and P. Chentsal Rao, respectively, are well done.

As with most books which consist of a series of essays, this book can be criticized for covering a broad area and many different topics. Some topics are much more thoroughly treated than others, though a few are treated in much depth. Most of the book, however, is informative, interesting, and easy to read.

MERVIN G. SMITH
The Ohio State University

Johnston, Bruce F., *Agriculture and Economic Development: The Relevance of the Japanese Experience*, Stanford, Food Research Institute, 1967, 61 pp. ($2.00). Reprinted from *Food Research Institute Studies*, Vol. VI, No. 3, 1966, pp. 251-312

This monograph represents the most complete effort available in English to sift from the historical record of Japanese agricultural development since the Meiji restoration (1868) its significance for the formulation of agricultural development strategies in contemporary underdeveloped countries. It culminates over two decades of scholarly research on the Japanese economy by Johnston himself and builds upon the careful work of Japanese scholars such as Ohkawa, Ogura, and their associates.

Johnston points out that a "consensus seems to have emerged regarding the strategic role of agricultural development in the economic growth of Japan" and that three features of agriculture's role have been widely recognized: (*a*) "Agricultural output has been increased with remarkably small demands on the critically scarce resources of capital and foreign exchange . . . within the framework of the existing small-scale agriculture." (*b*) "Agricultural and industrial development went forward together in a process of "simultaneous growth." (*c*) "The gains in agricultural productivity were of strategic importance in

making possible the increase in savings and investment that were a necessary condition for industrial expansion" [p. 252].

In Johnston's view, the major significance of the Japanese experience for contemporary underdeveloped economies is the success of the Japanese in drastically raising crop yields at low cost in terms of the scarce resources of capital and foreign exchange within a system of small-scale, labor-intensive agriculture. He is optimistic that contemporary underdeveloped countries also confront very substantial opportunities for increasing production "through yield-increasing innovations with fairly small investments in fertilizers and other complementary inputs" [p. 301], thus permitting a higher proportion of the scarce resources of capital and foreign exchange to be allocated to the expansion of output and employment in the nonfarm sectors. Johnston further argues that attempts to follow what he characterizes as the Mexican model—"to ignore the mass of the rural population . . . in an effort to develop a really modern sub-sector of large-scale, capital-intensive units in the expectation that in due course the families thus bypassed will be absorbed with the growth of output and employment in industry and large commercial farm enterprises" [p. 300]—is not realistic in view of population growth rates which preclude declines in the agricultural labor force within the foreseeable future in most developing countries.

There are two major criticisms which I would make of Johnston's work. The first is his unsystematic approach to the economic interpretation of Japanese historical experience. The second is his optimistic view of the relevance of the Japanese experience.

I applaud Johnston's refusal to be bound by either (*a*) the narrow formalism with which some analysts have attempted to force Japanese historical experience into one of the several two-sector models, or (*b*) an approach which would slice Japanese agricultural history into a series of neat linear stages. At the same time, I would insist that any attempt to interpret economic history outside of the framework of a carefully articulated model runs the danger of degenerating into mere "economic storytelling." In this case, I particularly regret that Johnston did not devote more time to the systematic development of the formal structure and logical implications for agricultural development strategy of the alternative "Mexican" and "Japanese" models of agricultural development which he characterizes [pp. 285–287]. At the very least, a more formal framework might have permitted greater selectivity in his organization of the historical materials. There are places, particularly in sections I and II, where it appears that additional references have simply been "dumped" into the text, with little judgment as to their significance.

In my opinion, Johnston seriously overestimates the relevance of the Japanese experience for the contemporary underdeveloped countries of South and Southeast Asia. Johnston's emphasis on the scope for rapid productivity changes within the framework of a small-scale, labor-intensive peasant agriculture is clearly valid, and its significance can hardly be overemphasized. The potential for yield-increasing innovations is very substantial. It seems clear, however, that the realization of the yield potentials inherent in the new wheat, rice, sorghum, millet, and other crop varieties that are becoming available in many areas will require very substantial investments in irrigation and water control, in capacity

to produce fertilizer and other agricultural chemicals, and in transportation and marketing facilities, if these potentials are to be realized. In the Japanese case many of the infrastructure investments had already been made in the Tokugawa (before 1868) period, thus setting the stage for the rapid diffusion of the biological and chemical technologies during the Meiji period.

In my judgment, the most significant feature of the Japanese experience was that Japan was able to "invent," within the first two decades after the beginning of the period of modernization, a set of institutions which were capable of producing and disseminating a constantly changing biological and chemical agricultural technology suited to the specific structural and ecological characteristics of Japanese agriculture.

Vernon W. Ruttan
University of Minnesota

Kneese, Allen V., and Stephen C. Smith, eds., *Water Research*, Baltimore, The Johns Hopkins Press for Resources for the Future, Inc., 1966, vii + 526 pp. ($12.50)

The disciplines of economics, law, engineering, geography, regional planning, and political science are represented in this book based on the papers presented at the 1965 Western Resource Conference. The book's 26 articles, plus an introduction by Kneese, are divided into seven rather arbitrary sections. One can speculate that the organization of the articles into sections follows the order of the presentation at the original conference. The lack of continuity, a fault of most books based on conference proceedings, is present in this volume. But the general excellence of the articles soon overshadows this minor annoyance.

A more appropriate title for the book might be "The Gospel on Water According to RFF." This comment should not be construed as derogatory; it is rather a recognition of the fact that nearly all of the social-science-oriented articles were written by members of RFF's staff or by researchers working under a grant from that organization. Results from research supported by other public and private agencies have not received "equal billing" in this volume.

It is impossible to review all 26 articles or even the 18 which are oriented to the social sciences. Thus, it seems more appropriate to single out a few articles presented by men with different professional interests than to reproduce the table of contents.

One expects excellence from Kenneth Arrow, and his article and bibliography on "Discounting and Public Investment Criteria" is indeed excellent. The traditional "interest rate problem" associated with the evaluation of public investments is formulated and treated as an explicit optimization problem. Arrow also presents an interesting digression on the relationship between discounting and risk, contending that "the optimal policy for the government is to reckon uncertain benefits and costs at their expected value and then discount the resulting stream at the same rates as used for riskless investments" [p. 17].

Alternative systems of water quality management on the Potomac Estuary are discussed by Robert Davis. His integration of engineering and economics is designed to answer the two important questions in water quality management: What is the optimum scale of expenditure? and What is the least-cost solution, given the scale of output? The author emphasizes the need for considering alternative techniques in water quality management and indicates the high economic costs which may result when planning is restricted to specific techniques such as low flow augmentation.

Hubert Marshall, a political scientist, presents a wide-ranging inquiry into the politics of water development. His research, based on interviews with congressmen and their assistants, indicated that "there is widespread appreciation in Congress that benefit–cost ratios are inflated and that they are not a reliable index of economic efficiency. . . . Yet the unreliability of benefit–cost ratios is never openly discussed, except by one or two mavericks in the Senate" [p. 296]. Marshall also discusses the political logic associated with tacit acceptance of the unreliable benefit–cost ratios in the General Accounting Office, the Bureau of the Budget, and the construction agencies. He does not suggest discarding benefit–cost analysis but rather pleads for a professional awareness from the economists in the federal agencies and for support from the academic community in the form of a statement outlining minimum standards for economic evaluation.

These three articles indicate the broad scope of the research activity in the water resource field. There are many other excellent articles, including discussions of hydrologic systems and the problems and potentials of seawater conversion.

In fact, there is only one article with which I find myself in major disagreement. Arthur Maass, in his discussion of the relevance of benefit–cost analysis to public investment decisions, disapproves of the importance attached to the objective of economic efficiency. Most economists, I think, would agree with Maass on the need for including objectives other than efficiency in public decision making. My disagreement with Maass is that the inclusion of other objectives does not require that economics be relegated to a system for considering "the most efficient way of satisfying a fixed requirement" [p. 322].

Maass also suggests that secondary benefits are "benefit[s] in support of an objective other than efficiency" [p. 314]. He admits the possibility of induced secondary benefits but dismisses them as being unimportant. In my view, this erroneous interpretation of the concept of secondary benefits hinders rather than stimulates the inclusion of a distribution objective as a goal of public investment.

Although the nature of the book will probably exclude it from consideration as a text for a graduate course in this area, I should think it would appear frequently on supplemental reading lists.

J. DEAN JANSMA
The Pennsylvania State University

Nõu, Joosep, ***Studies in the Development of Agricultural Economics in Europe***, **Uppsala (Sweden), Almquist & Wicksells Boktryckeri A/b, 1967, 611 pp. (Reprinted from Lantbrukshögskolans Annaler, Vol. 33, 1–611, 1967, Annals of the Agricultural College of Sweden)**

This book is an ambitious attempt to trace the history of agricultural economics thought in Europe, including European Russia, from its modern beginnings in the eighteenth century to the present day, in the middle of the twentieth century. To the best of our knowledge, it is the first such comprehensive undertaking to use an integrated approach crossing the national and language boundaries. In view of the multitude of such barriers, it is no mean task, and it takes a virtual polyglot to make access to the original source material possible. In addition to such major European languages as English, French, German, Italian, and Russian, important contributions are included in a number of other languages such as Dutch, Danish, Norwegian, Swedish, Polish, Czech, Croatian, Serbian. The list of literature cited includes an impressive 749 titles on 39 pages.

The author, possessing a working knowledge in the five major languages and a number of others, is eminently qualified to undertake this difficult, and in many ways pioneering, task. Educated in Estonia in the broad field of agricultural sciences, he took his Master's degree in agricultural economics at Tartu University in 1933. Having fled from Bolshevist occupation of his native country to Sweden in 1944, he specialized in the history of agricultural economics in Europe and took his agriculture licentiate degree in this field. The publication at hand is the doctoral dissertation submitted to the Agricultural College of Sweden in Ultuna. Purposeful research for the dissertation was begun about ten years ago, and in the course of collecting material the author visited most of the countries in western and central Europe, interviewed leading agricultural economists, searched libraries for forgotten and rare publications, and assembled a collection of portraits of prominent agricultural economists, 35 of which have been reproduced in the book. The study exceeds considerably the traditional limits of doctoral dissertations.

The two introductory chapters define the objectives and methods of the study and review briefly the related literature. Chapter 3 analyzes agricultural economic views of the Physiocrats, who presented one of the first coherent doctrines in economics in which agriculture played a prominent role. Chapter 4 traces the agricultural economic ideas of Arthur Young (1740–1820) in his prolific literary legacy. Although Young did not advance a coherent or systematized agricultural economic doctrine, he nevertheless gave a direct impetus to the development of such. A German physician, Albrecht D. Thaer (1752–1828), was an eager student of English agriculture and an ardent disciple of Arthur Young. He popularized Young's ideas in Germany (at times engaging in outright plagiarism of Young by not bothering to disclose his source), established in 1806 the first agricultural academy (college) in Germany, and published his celebrated *Grundsätze der rationellen Landwirtschaft (Principles of Rational Agriculture)*, which has made him the founding father of the broad field of agricultural sciences in the German-language sphere. Chapter 5 dis-

cusses the role of A. D. Thaer in the development of agricultural economics. Chapter 6 is devoted to another German, the founder of the location theory in agriculture and economics—Johann Heinrich von Thunen (1783–1850)—and his *The Isolated State.* Thunen distinguished himself by placing heavy emphasis on abstract-deductive method as a research tool, while Thaer used largely the empirical-inductive approach. These two individuals, Thaer and Thunen, and their different methodological approaches influenced more than anyone else future generations of agricultural economists in all language-regions in Europe. Their disciples can be traced to our days. Chapters 7–10 discuss the development of agricultural economics doctrine during the last century in the leading European countries—Germany, Switzerland, Austro-Hungary, Italy, and Russia. The last chapter attempts to systematize and summarize the epochs and schools in Europe. Farm management, type of farming, farm accounting, and farm appraisal have received major attention, whereas agricultural policy, marketing, and work simplification are treated in passing.

Although the study as a whole is of great interest, including a wealth of details, chapters 7–10 are probably the most interesting and most original. Here the author has brought to light men and works that have been almost completely forgotten—and unjustly so—and has expanded our knowledge of the early development of agricultural economics in various European countries. He has traced the movements of scientific ideas across the national frontiers and language barriers. Relatively little known are the close ideological ties of the founders of Russian agricultural economics in the second half of the last century with the then-current teachings in central and western Europe. The second generation of Russian agricultural economists is better known in the West through the German translations of the works of its most prominent representative, Alexander Chayanov.[1] The eclipse of their original theories on peasant farming and the liquidation of the peasant in the great Soviet purges in the late 1930's are briefly indicated.

Little of a comparable nature has been available so far in English on the history of agricultural economics in Europe. In this respect, the extensive study by J. Nõu fills a void. The strength of this work lies in its great abundance of factual material, which makes it an authoritative source of reference for all future workers in the field. The author has examined a large number of significant publications in agricultural economics and related disciplines and has briefly summarized their contents or characterized their nature.

In this strength of the work lies also its most evident weakness. The author has not always been able to systematize this overabundance of facts nor weed out some repetitions.

The work was originally written in Swedish and then translated into English by two individuals, evidently not agricultural economists themselves. This method always involves some problems and risks. At places the style appears wordy, the translation slavishly literal, and the English not sufficiently stream-

[1] Chayanov's works are being made available at present by Johnson Reprint Corporation, New York, and S. R. Publishers, Ltd., England. See their recent leaflet, "Selected Agrarian Economic Studies" by A. V. Chayanov.

lined. Occasional technical terms, rendered in awkward English or outright erroneously, are likely to cause some confusion. These minor imperfections, however, concern the form rather than the substance and do not affect significantly the essential value of the work. It was a fortunate idea to make the findings of this basic study available to the English-speaking world.

ELMAR JARVESOO
University of Massachusetts

Ottoson, Howard W., Eleanor M. Birch, Philip A. Henderson, and A. H. Anderson, *Land and People in the Northern Plains Transition Area*, Lincoln, University of Nebraska Press, 1966, xiv + 362 pp. ($7.95)

This is clearly an in-depth study in regional economics and, given its focus on the inner workings of the geographically most sensitive portion of the Great Plains economic and social structure, has general value for studies of the forces explaining the socioeconomic status of any given region. The volume is reminiscent of and rivalled only by John D. Black's masterful work on *The Rural Economy of New England*. The authors share with Professor Black the scholarly and practical perceptions necessary to examine the basics of a series of adjustment problems that face transitional areas—transitional in time or place. The two forms of transition are simultaneous in this case and involve the Northern Great Plains, bracketed roughly between the 98° and 100° meridians, and involving important segments of the two Dakotas, Nebraska, and Kansas. While the collection of socioeconomic problems confronting this area is indeed unusual and interesting for analysis, other collections of problems exist for other areas, and the work of Professor Ottoson and his colleagues must be recognized as having considerable methodological value for guiding such work elsewhere. The volume is an application of the historical and case research methods at their best. Its prolific statistics alone recommend it as a basebook for anyone having a professional interest in the Great Plains as a region.

I find little in the book to criticize or oppose, but it does provide an opportunity to state some minor points of agreement or disagreement with definitions or concepts. Involved in turn are the "family farm" idea, the rectangular survey system, and the concept of economic growth.

Happily, the authors argue for a flexible concept of size of farm in the Plains area [pp. 152–153], and thus recognize that a socially "optimum" farm size is conditioned by (rather than conditions) social and economic objectives, available resources, and the pricing system. One need only transpose the term "family farm" to "farm family" to see clearly our real objective in maintaining healthy rural economies.

In a related discussion of the rectangular survey, the authors describe very well [pp. 150–151] the difficulties in land use and farm planning that result from too close a conformity to grid lines. I question, however, whether the system itself should be indicated on these points. After all, it was intended to be

only a systematic method of land identification. In this respect it has turned out to be highly efficient, easily understood, and, therefore, widely copied.

As an index to economic growth, in comparing the Northern Plains to other regions, the authors employ changes in per capita incomes [pp. 131–137]. I recognize that this definition of growth is very commonly used and is acceptable, but I am still mindful of Boulding's distinction between growth and social progress (see his *Economic Analysis*, rev. ed., 1948, pp. 646–664). It is easy to conceive of situations where a region's real economic product has shown a substantial increase but, because of a greater increase in population, its per capita income has fallen. Can one really say that its economy has not grown? Conversely, real output may remain stable or decline but decline less rapidly than population, with an increase in per capita income the net result. Can one then say that the economy has grown? To me it seems best to reserve the term *economic growth* to refer only to major indicators such as total real income, to make time-series or geographic comparisons on this basis, and then to introduce into social welfare terms such qualifying factors as population and income distribution. Otherwise, there may be a tendency to overemphasize the importance of the latter in regional development or adjustment studies.

Roughly one-third of the book deals at length with feasible resource, managerial, community, and public agency program adjustments feasible in the Northern Plains region. The role of social science research in guiding such adjustments is spelled out clearly, particularly in the discussion of the activities of the Great Plains Agricultural Council. Since agreeing to review the book, I have been privileged to see Dr. Ottoson's paper on "Macro-economic Research and Great Plains Agriculture" contained in the proceedings volume of an April 1967 seminar at Lincoln on "Emerging Research Needs in a Dynamic Great Plains Economy." The paper is a fairly exhaustive review of social science research literature on the Great Plains, a proper interpretation of which is greatly facilitated by reference to his major work on *Land and People in the Northern Plains Transition Area.*

GEORGE A. PAVELIS
Economic Research Service
USDA

Pincus, John, *Trade, Aid and Development—the Rich and Poor Nations,* New York and London, McGraw-Hill for the Council on Foreign Relations, 1967, xv + 400 pp. ($10)

In this interesting, informative, and provocative book, Dr. Pincus attempts to bring together the various elements of international economic policy as they bear on the economic development of underdeveloped countries. The research and writing of this book were sponsored by the Council on Foreign Relations. The author has not tried to cover all aspects of development thoroughly in a single volume, since one of the major elements, international monetary arrangements, is discussed elsewhere. A second element, the effects of the domestic

economic policies of poor countries on their trade, capital flows, and growth, is omitted because of limitations of time and space.

The first two chapters present in general terms the political and economic bases for foreign aid and trade. Next, there are two chapters which, as the author admits, digress from the main theme. These chapters review classical, neoclassical, and contemporary trade and development theory. In our opinion, the author could have improved his presentation by eliminating this digression and incorporating its contribution where applicable elsewhere. He could also have tightened up the focus on his theme. Of particular note are the references to what was written elsewhere in the book. For example, in Chapter 5, on page 161, a list of external constraints "listed in Chapter 4" is repeated. Again, in Chapter 5, page 165, reference is made to "data of Chapter 2," and also in Chapter 5, on page 166, he indicates that "these conditions were discussed in Chapter 4 and are summarized here."

Three chapters (5–7) deal broadly with the principal policy issues of trade and development, embracing choices and issues of commercial trade policy for manufactured products and commodity trade. Chapter 8 examines the demand for capital in the developed and the less-developed countries (LDC's) in terms of the requirements, levels, forms, and sources of aid and the role of foreign private investment. Finally, a summary chapter entitled "Policy for the Rich Nations" reviews the costs and benefits of foreign aid and surveys the limitations and prospects of trade, aid, and investment policies.

Dr. Pincus argues that each country which offers aid or other concessions does so in the expectation of receiving benefits. Testimony to this, he claims, is evidenced by the widespread doubts and continuing controversies about the merits of aid in the major donor countries.

Pincus states that aid and trade may substitute for each other to a limited extent and may also act to reinforce or offset each other's effects. Assuming that rich countries want to help poor ones but are reluctant to raise aid levels, he suggests that the rich should seek to promote trade and the poor to promote both aid and trade. The United Nations Conference on Trade and Development (UNCTAD), which met in Geneva from March to June 1964, gave clear expression to three different conceptions of the international economy in addition to the Soviet view. The author indicates that in contrast to the advanced countries (excluding the USSR), which were reasonably content with their present level and share of the world's income, the less-developed countries were profoundly dissatisfied with the present distribution of world income. The author belabors the United States for what he regards as an excessively rigorous verbal devotion to liberal trade principles that it violates daily, and for failing to propose positive measures beyond those expected from the long-oversold GATT negotiations. He asserts that basically the United States has never decided what it wants to gain from its aid to underdeveloped countries, although United States aid policy has stressed helping LDC's toward self-sufficiency.

Dr. Pincus believes that trade and investment promote a market discipline that stimulates growth, while aid may not. Trade, by enriching both parties, simultaneously makes it easier for the rich to give aid and less necessary for the poor to obtain it as a condition of growth. He indicates that there is clearly no

unique relation between trade and economic development. The percentage growth of Atlantic Community exports was nearly twice as great as its income growth during the past decade; underdeveloped countries' exports rose a little slower than income. Yet income in the two areas grew at nearly the same rate. These findings, he emphasizes, underline the error inherent in equating income growth and trade growth uniquely for all countries. Even though some countries (Israel, Jordan, and Taiwan) have received an important stimulus from foreign aid, the mixed record of achievement reveals the inability of any single formula to explain economic growth, or its absence, in the LDC's. Each underdeveloped country is a special case, and each will develop differently.

Pincus's approach will be welcomed by all those who feel that a policy is impractical when it calls upon rich nations to give more aid and at the same time to renounce the exercise of political power. For truly effective economic aid, he calls for enlightened self-awareness on both sides: a clear understanding by the donor nation of what it can hope to achieve through economic concessions and what it will receive in return and a clear knowledge on the part of the recipient nation of what is expected of it and what "strings" are attached to the trade or aid concessions received.

ROBERT L. TONTZ *and*
ISAAC E. LEMON
Economic Research Service
USDA

Toma, Peter A., *The Politics of Food for Peace*, Tucson, The University of Arizona Press, 1967, xiv + 195 pp. ($3.95)

This slender book is illustrative of the growing trend toward quantitative research in the area variously known as government, public administration, and political science. The special case under scrutiny is Public Law 480, often called the Food for Peace program. The result of the effort is a useful book providing concise history, both narrative and statistical. The work meets generally high standards of objectivity and accuracy.

During 1964 and 1965 Professor Toma was a member of a research team on Food for Peace sponsored by the Agency for International Development. He has drawn on other sources: the 1964 Arizona bulletin by Menzie and Crouch, the 1965 book by McClellan and Clare, and the *Congressional Quarterly*. These diverse sources are not fully integrated in Toma's book and connective tissue is lacking. The result is a certain joltiness as the reader proceeds from one section to another.

The book concentrates on the period 1954–1964, with some introductory material. There is brief narrative treatment of the major changes in the program since that time. The major issue during the 1954–1964 period, correctly identified by Toma, was the degree to which Public Law 480 was a farm program and the degree to which it was a part of our foreign economic policy. Numerous related and subordinate issues are reported.

The book reports [p. 64] an "uncooperative Republican Administration" as an obstacle to the program, and states that "until the 1958 Congressional elections, Public Law 480 suffered from the influence Eisenhower exerted on the Congress." This is a surprising comment in view of the fact that the program was recommended to the Congress by a Republican Administration, was enacted by a Republican Congress, and under President Eisenhower reached a level of activity greater than that which has recently prevailed.

Detailed examination is made of the revising and extending of the Food for Peace program in 1964. A more interesting study would have been the extension and amendments of 1966, which involved deeper and more fundamental changes.

Toma reports the force of various factors influencing the House and Senate Agricultural Committees with respect to Public Law 480. In order of intensity, these were presidential support, attendance at hearings, political party, Public Law 480 constituency, age, farm constituency, liberal–conservative orientation, seniority, occupation, and party unity. The difficulty of separately identifying these interrelated forces is at once apparent; the difficulty of measuring their influence will also be clear. And following through the analysis can become tedious. Trivia sometimes obscure what is central.

Despite these problems, the discipline of quantification yields a clear plus, in my view. Without it, myth and conjecture take on too large a role. In the political area as in other sectors of social science, the blending of judgment with empirical work appears to give the most useful results.

Toma concludes by looking ahead to the time when the Congress must make a choice between some one concept and some combination of three different concepts. One, identified with Senator McGovern, involves a large program that would synthesize agricultural interests with national security. Another, identified with Senator Ellender, visualizes the gradual phasing out of large-scale food assistance. Yet another, associated with Senator Fulbright, would see direct food shipments dissociated from farm policy and made into a part of our foreign aid program, increasingly provided through multilateral organizations.

I offer one final comment. All footnotes are carried at the back of the book, by chapters, with the chapters numerically identified. When a footnote is encountered, the reader must first page back to learn the number of the chapter he is reading. Then he pages forward to the footnote section and finds the number of his chapter. By this time, having forgotten the number of the footnote, he goes back again to the point at which he was reading and is lucky if he has held the place with his finger. By the time he has gone forward again and found the footnote, his thread of thought has become lost and he must reread the footnoted passage. The alternative to this procedure is to ignore the footnotes altogether, a difficult thing for the scholarly conscience. Of all alleged solutions to the footnote problem, the one offered in this book is probably the worst.

DON PAARLBERG
Purdue University

Books for listing in this section should be sent to the Book Review Editor (see inside front cover for address).

Books Received

Barnard, Jerald R., *Design and Use of Social Accounting Systems in State Development Planning,* Iowa City, The University of Iowa, 1967, x + 163 pp. $3.50.

Bell, F. W., and J. E. Hazleton, eds., *Recent Developments and Research in Fisheries Economics,* Dobbs Ferry, N.Y., Oceana Publications, Inc., for The New England Economic Research Foundation, 1967, xv + 233 pp. Price unknown.

California Department of Water Resources, *Selected Bibliography of Resource Development,* Supplement No. 1, June 1967, 259 pp. Price unknown.

Clark, Colin, *The Economics of Irrigation,* New York, Pergamon Press, 1967, ix + 116 pp. 35s.

Clawson, Marion, *The Federal Lands Since 1956: Recent Trends in Use and Management,* Baltimore, The Johns Hopkins Press, 1967, xi + 113 pp. $4.00.

Cox, Edwin B., ed., *Basic Tables in Business and Economics,* New York, McGraw-Hill Book Co., 1967, xiv + 399 pp. $3.95.

Ezekiel, Hannan, *The Pattern of Investment and Economic Development,* Bombay, University of Bombay, 1967, Series in Economics No. 13, 119 pp. Rs. 9.50.

Gaffney, Mason, ed., *Extractive Resources and Taxation,* Madison, The University of Wisconsin Press, 1967, xviii + 450 pp. $8.00.

Golembiewski, Robert T., and Frank Gibson, eds., *Managerial Behavior and Organization Demands: Management as a Linking of Levels of Interaction,* Chicago, Rand McNally & Co., 1967, viii + 440 pp. $3.95 paper, $8.50 cloth.

Hansen, Roger D., *Central America: Regional Integration and Economic Development,* Studies in Development Progress, No. 1, Washington, D.C., National Planning Association, 1967, xvi + 106 pp. $2.50.

Marenco, Gaetano, and Michele de Benedictis, *La Localizzazione Della Produzione Agricola,* Edizioni Scientifiche Italiane Napoli, 1967, 53 pp. Price unknown.

Marks, Norton E., and Robert M. Taylor, eds., *Marketing Logistics:*

Perspectives and Viewpoints, New York, John Wiley & Sons, Inc., 1967. $8.95.

Miller, Clarence J., ed., *Marketing and Economic Development: Readings in Agribusiness Research*, Lincoln, University of Nebraska Press, 1967, 422 pp. $3.25.

Moore, Ernest G., *The Agricultural Research Service*, New York, Frederick A. Praeger, Publisher, 1967, xii + 244 pp. $5.95.

National Industrial Conference Board, Paul Biederman, ed., *Economic Almanac, 1967–1968 Business Factbook*, New York, The Macmillan Company, 1967, vi + 655 pp. $8.95 hardbound, $2.95 paper.

Nelson, Aaron G., and William G. Murray, *Agricultural Finance*, 5th ed., Ames, Iowa State University Press, 1967, x + 561 pp. Price unknown.

Papanek, Gustav F., *Pakistan's Development: Social Goals and Private Incentives*, Cambridge, Mass., Harvard University Press, 1967, xxii + 354 pp. $8.95.

Philpott, B. P., H. T. D. Acland, and A. J. Tairo, *Statistics of Production, Trade Flows and Consumption of Wool & Wool-Type Textiles*, Canterbury, New Zealand, Lincoln College, 1967, 36 pp. Price unknown.

Pollack, Norman, ed., *The Populist Mind*, Indianapolis, The Bobbs-Merrill Co., Inc., 1967, lxiii + 539 pp. $3.75.

Press, Charles, and Alan Arian, eds., *Empathy and Ideology: Aspects of Administrative Innovation*, Chicago, Rand McNally & Co., 1966, 258 pp. $3.50 paper, $6.00 cloth.

Research Center, School of Business and Public Administration, *Research Organization and Activity*, Annual Report 1966-67, Columbia, University of Missouri, 1967, 75 pp. Price unknown.

Roy, E. P., *Exploring Agribusiness*, Danville, Ill., The Interstate Printers and Publishers, 1967, 295 pp. $8.25.

Salter, Leonard A. Jr., *A Critical Review of Research in Land Economics*, Madison, The University of Wisconsin Press, 1967, xix + 258 pp. $7.50 cloth, $2.95 paper.

Saville, Lloyd, *Regional Economic Development in Italy*, Durham, N.C., Duke University Press, 1967, xiv + 191 pp. $7.00.

Southworth, Herman M., and Bruce F. Johnston, eds., *Agricultural Development and Economic Growth*, Ithaca, Cornell University Press, 1967, xv + 608 pp. Price unknown.

Stevens, Benjamin H., and Carolyn A. Brackett, *Industrial Location: A Review and Annotated Bibliography of Theoretical, Empirical and Case Studies*, Bibliography Series No. 3, Philadelphia, Regional Science Research Institute, 1967, v + 199 pp. Price unknown.

Tabard, Nicole, *et al.*, *Les conditions de vie des familles*, Paris, Centre de Recherches et de Documentation and Union Nationale des Caisses d'Allocations Familiales, 1967, x + 697 pp. Price unknown.

Tinbergen, J., *Economic Policy: Principles and Design*, Chicago, Rand McNally & Co., 1967, xxviii + 276 pp. $7.50.

Van den Noort, P. C., *Size and Distribution of Agricultural Income in the Netherlands, 1923–1963*, Wageningen, Centrum voor Landbouwpublikaties en Landbouwdocumentatie, 1965, 164 pp. Price unknown.

Announcements

1968 AAEA ANNUAL MEETING

The 1968 AAEA Annual Meeting will be held jointly with the Western Farm Economic Association, on August 18–21, 1968, in Bozeman, Montana. Suggestions for the program should be sent to President C. E. Bishop, Vice President, The University of North Carolina, P.O. Box 269, Chapel Hill, North Carolina 27514.

Dr. Clarence W. Jensen, Head of the Department of Agricultural Economics, Montana State University, Bozeman, Montana, is chairman of the local arrangements committee.

CONTRIBUTED PAPERS—1968 AAEA ANNUAL MEETING

Contributed papers in any area of agricultural economics are solicited. Priority in selection will be given to papers that identify new or neglected problems, or that demonstrate or propose new approaches, new concepts, or improved methods applicable to recognized problems. Contributions treating collegiate and adult teaching as well as research are encouraged.

At least four sectional meetings are planned for contributed papers with a maximum of four papers in each session. The specific subject matter groupings for each session will be determined by the papers submitted.

Rules for Submitting Contributed Papers

1. The maximum length of any contributed paper shall be seven double-spaced typed pages including text and all other material such as footnotes, tables, and charts. Place all references, alphabetized by author, in a numbered list at the end of the paper in a section titled "References." When you refer in the text to a publication on this list, insert its number in brackets, including specific page number if necessary. Example: [7, p. 643]. See "Guide for Submitting Manuscripts" on the inside of the back cover of the *American Journal of Agricultural Economics.*

2. Five copies of the paper and a one-page abstract are to be submitted to the general chairman before May 1, 1967. The general chairman will group the papers and forward them to section chairmen, notifying each author of the group to which his paper was assigned. The abstract will be used as a guide for grouping the papers.

3. It shall be the responsibility of each section chairman in consultation with several of his departmental colleagues to select four papers for presentation at the annual meeting.

4. It is recommended that 50 copies of the contributed papers be brought to the annual meeting by the author for distribution.

The following committee is in charge of the program: Loyd Glover, South Dakota State University, general chairman; Travis Manning, University of Alberta; Milton Manuel, Kansas State University; John R. Schmidt, University of Wisconsin; and Kenneth Tefertiller, University of Florida.

Requests for further details should be directed to the general chairman, Loyd Glover.

UNDERGRADUATE DEBATE, PUBLIC SPEAKING, AND ESSAY COMPETITIONS

Competition is open to any undergraduate student interested in agricultural economics. Participants are encouraged to become members of chartered student-section affiliates of the American Agricultural Economics Association but such membership is not required to enter the various contests. No individual student may enter both the debate and the public speaking competitions in the same year.

Public Speaking Competition

The public speaking may be on any topic in the area of agricultural economics. Each speech will be limited to 10 minutes' duration.

Chartered chapters or individuals must declare their intention of participating in the public speaking competition by writing not later than June 1, 1968, to Kenneth B. Boggs, Chairman, AAEA Student Activities Committee, Department of Agricultural Economics, University of Missouri, Columbia, Missouri 65201.

Debate Competition

The topic to be debated in 1968 is

Resolved: That the government should establish a program to retard the movement of people from the farm to the city.

A declaration of intention to participate in the debate competition must be made in writing not later than June 1, 1968, to Kenneth B. Boggs, at the address given above. Names of contestants and/or alternates and coaches, along with the mailing address of each, should be included. Not more than one debate team from one school may participate in the debate contest.

Student Essay Contest

The essay contest does not require attendance at our annual summer meeting. It was developed primarily to provide an opportunity to participate for students who find it impossible to attend the annual meetings and for students whose abilities and interest tend to be in research and/or writing. The development and preparation of a manuscript for purposes of publication is one of the objectives of this contest. Essays may deal with any topic in agricultural economics, agricultural industries, or rural sociology. The 1968 award paper will be published in the 1968 Proceedings issue.

Manuscripts should not exceed 2,500 words in length and should be pre-

pared according to instructions appearing on the inside of the back cover of the *American Journal of Agricultural Economics.* Manuscripts must be submitted in triplicate by July 1, 1968, to Robert Taylor, Department of Agricultural Economics, Purdue University, Lafayette, Indiana 47907.

DUES

Dues for 1968 are payable. The dues rates are as follows:
American Agricultural Economics Association—$10.00
Junior Membership, AAEA—$5.00 (Graduate Students, 3-year maximum)
Joint Membership, AAEA and WFEA—$12.50
Joint Membership, AAEA and CAES—$16.50
Joint Membership, AAEA, WFEA, and CAES—$19.50
Please mail your check, payable to the American Agricultural Economics Association or AAEA, to C. D. Kearl, Secretary–Treasurer, AAEA, Department of Agricultural Economics, Cornell University, Ithaca, New York 14850.

BACK ISSUES OF *JOURNAL OF FARM ECONOMICS* NEEDED

The secretary–treasurer of the AAEA is authorized to pay $1.00 each for any of the issues of the *JFE* listed below. Copies of the February 1965 issue particularly are needed.

Year	*Volume*	*Issues*	*Year*	*Volume*	*Issues*
1919	1	1, 2, 3	1945	27	2, 3, 4
1920	2	1, 2, 3, 4	1946	28	3
1921	3	1, 2, 3, 4	1947	29	1
1922	4	1, 2, 3, 4	1955	37	2, 5
1923	5	1, 2	1956	38	1, 2
1924	6	1, 2, 3, I	1957	39	1, 3–2
1925	7	1, 2, 4, I	1958	40	2, 3
1926	8	2, 3, 4, I	1961	43	4–1
1935	17	1	1962	44	3
1943	25	3	1965	47	1

Journals should be mailed to C. Del Mar Kearl, Department of Agricultural Economics, 453 Warren Hall, Cornell University, Ithaca, New York 14850.

SYMPOSIUM

On the occasion of its fiftieth anniversary, the Agricultural University ("Landbouwhogeschool"), Wageningen, The Netherlands, will hold a scientific symposium from March 4 to 6, 1968. The theme of the symposium will be "Agricultural sciences and the world food supply."

News Notes

PERSONAL

Martin E. Abel, formerly staff assistant to the administrator, ERS, USDA, has been named deputy assistant secretary for international affairs. He will provide leadership for USDA responsibilities in food aid and technical assistance programs.

John W. Adams, who is completing a Ph.D. degree at Washington State University, has been appointed assistant professor in the Department of Agricultural Economics and Sociology, Texas A&M University, where he is engaged in teaching and research in production economics.

Badie J. Al-Kaddo, Ph.D. University of Illinois, has returned to Iraq and an assignment in the Iraqi government service.

R. J. Amick, formerly associate economist at the Georgia Agricultural Experiment Station, has accepted a position as associate professor of agricultural economics at the University of Kentucky, effective January 1, 1968.

Kenneth L. Bachman, director, Foreign Development and Trade Division, ERS, USDA, has accepted a position with FAO in Rome as director of the Economic Analysis Division in the Department of Economics and Social Affairs.

William B. Back has rejoined the Resource Institutions Branch, Natural Resource Economics Division, ERS, USDA, in Washington, D.C., after working at the National Advisory Commission on Rural Poverty for the past year.

C. K. Baker, formerly extension economist in farm organization, Department of Agricultural Economics and Sociology, Texas A&M University, has joined the Texas A&M University–AID Project in Santo Domingo, Dominican Republic, as an agricultural economist (marketing).

Randolph Barker, recently of the Cornell University Department of Agricultural Economics on a two-year assignment at the University of the Philippines, has resigned to accept a position with the International Rice Research Institute at Los Banos. He will continue to hold courtesy appointments on the faculties of the University of the Philippines and Cornell University.

Paul W. Barkley, formerly on the faculty at Colorado State University, joined the Agricultural Economics Department at Washington State University in September. He will do research and teaching in resource economics, economic development, income distribution, and welfare economics.

Edmund R. Barmettler has resigned from the Department of Agricultural Economics at the University of Hawaii. He has accepted a position at the University of Nevada, effective September 1, 1967, as professor of agricultural economics and extension economist. His primary

work will be in extension and teaching.

George M. Beal, Department of Agricultural Economics, University of Maryland, has co-authored a book, *Institutional Factors Affecting the Growth and Functions of Norwegian Agricultural Cooperatives,* with Nils K. Nesheim, Oslo, Norway.

Manning Becker received the outstanding teaching award given by the School of Agriculture at Oregon State University. The award was presented at Faculty Day in September, 1967.

Shaul Ben-David is working with Professor Olin Forker in the Department of Agricultural Economics at Cornell University on some long-term projections for agriculture in New York State.

Andrzej Bernacki of the faculty of agricultural economics, Warsaw Agricultural University, has resumed his duties after spending a year in postdoctoral study at the University of Kentucky.

Nelson L. Bills, who completed the requirements for an M.S. in agricultural economics at West Virginia University during the summer, has accepted a position with the Economic Research Service, USDA, and is stationed at Washington State University.

Wendell Binkley, associate professor of agricultural economics at the University of Kentucky, continues on leave for another year to work with the Ford Foundation in India.

William E. Black has become extension economist in marketing and policy in the Department of Agricultural Economics and Sociology, Texas A&M University. He formerly was director, Economic and Marketing Research, Florida Citrus Commission.

George T. Blanch has retired as head of the Department of Agricultural Economics at Utah State University. He has been placed on emeritus status and will continue to work in the department. Dr. Blanch was head for 15 years.

John C. Blum has been appointed deputy administrator for regulatory programs, Consumer and Marketing Service, USDA, succeeding Clarence H. Girard. Mr. Blum had been Assistant Deputy Administrator since 1964.

Martin A. Blum, head of the Fruit Section, Commodity Analysis Branch, Economic and Statistical Analysis Division, Economic Research Service, left on September 8, 1967, to become director of the Cooperative Appraisal Division, Farmers Cooperative Service, USDA.

Michael D. Boehlje, who completed his Master of Science at Purdue University, is on the CIC Traveling Scholar Program at Iowa State University. He will complete his Ph.D. at Purdue University.

David H. Boyne assumed the chairmanship of the Department of Agricultural Economics and Rural Sociology at Ohio State University on November 1, 1967. Dr. Boyne was formerly a member of the faculty at Michigan State University.

Charles R. Brader was named head of the Fruit Section, Commodity Analysis Branch, Economic and Statistical Analysis Division, ERS, USDA, on September 25, 1967. He was formerly with the Office of Emergency Planning, Executive Office of the President.

Sergio Brandt, Ph.D. Ohio State Uni-

versity, is returning to Brazil. He will be working with the Division of Rural Economics, State of Sao Paulo, and with the OSU–University of Sao Paulo–AID contract.

Russell Brannon has completed his doctorate at the University of Wisconsin and joined the Department of Agricultural Economics at the University of Kentucky in September 1967 as assistant professor to do teaching and research in economic development.

George K. Brinegar, director of international agriculture programs and associate dean, University of Illinois College of Agriculture (also professor of agricultural economics), was appointed director of international programs, University of Illinois, in September 1967.

Aubrey J. Brown, chairman of the department of agricultural economics at the University of Kentucky for 21 years, requested and was granted a release from administrative duties to devote full time to teaching and research as professor of agricultural economics.

Lester R. Brown, administrator, International Agricultural Development Service, USDA, was selected in 1966 by the U.S. Jaycees as one of the ten outstanding young men in America for his contribution to a better understanding of the nature, dimensions, and immediacy of the world food problem and for anticipating the 1965 crop failure in India early enough to permit a massive and successful food rescue effort to be launched.

Joseph B. Bugliari, graduate of the Cornell Law School and Hamilton College, has joined the Cornell Department of Agricultural Economics as associate professor of agricultural and business law, and will also teach business law in the Cornell Graduate School of Business and Public Administration.

James O. Burnett has finished work on his M.S. degree at the University of Maryland and plans to enter military service.

Walter R. Butcher, Department of Agricultural Economics, Washington State University, is spending from November 1967 to June 1968 on a consulting assignment with the Systems Analysis Group, Office of Civil Functions, Department of the Army, Washington, D.C.

William N. Capener has been appointed associate professor in the Department of Agricultural Economics and Agricultural Business at New Mexico State University. He was formerly in livestock marketing research, MED, ERS, USDA.

James P. Cavin retired from his position as director of the Economic and Statistical Analysis Division, ERS, USDA, on October 6, 1967. Dr. Cavin had 31 years of government service, mostly in the Department of Agriculture. During World War II he served on the National Defense Advisory Commission and subsequently as associate head of the Food Price Division of the Office of Price Administration. Returning to the Department in 1943, he served first as associate head, then as head of the Division of Statistical and Historical Research in the Bureau of Agricultural Economics. From 1951 to 1954, he served in the Office of Statistical Standards in the Bureau of the Budget. He returned a second time to USDA in 1954, serving successively as chief of the Statistical and Historical Research Branch of the Agricultural Marketing Service, and as deputy director and director of the Eco-

nomic and Statistical Analysis Division.

William O. Champney joined the staff of the Division of Agricultural Economics and Education at the University of Nevada on September 1, 1967, as an assistant professor working in the area of marketing in a teaching and research position. He did his Ph.D. degree work at Kansas State University.

Raymond P. Christensen has been named acting director of the Foreign Development and Trade Division, ERS, USDA. He replaces Kenneth L. Bachman, who is now with FAO in Rome.

Walter E. Chryst, formerly with the Natural Resource Economics Division, ERS, USDA, and most recently on the staff of the National Advisory Commission on Food and Fiber, has been appointed professor of law and economics and director of economic research, Legal Institute of Agricultural and Resource Development, University of Mississippi.

Lewis E. Clark, agricultural business management specialist, Cooperative Extension Service, University of Maine, is on a two-year leave of absence to serve as a farm management specialist with the AID Mission in Afghanistan.

Arthur Conover, head of the Tobacco Section, Commodity Analysis Branch, Economic and Statistical Analysis Division, ERS, USDA, and well known throughout the Department and the tobacco world, retired early in October 1967.

James Conrad, doctoral candidate in agricultural economics at the University of Kentucky, has accepted a teaching position at West Baden College, West Baden, Indiana.

Neil Cook transferred from Stillwater, Oklahoma, to Little Rock, Arkansas, to become leader of the Southern Resource Group, Natural Resource Economics Division, ERS, USDA, effective July 1, 1967. He was formerly in charge of the watershed evaluation studies in the Washita River Basin at Stillwater.

James H. Copp has resigned his position as associate professor of rural sociology in the Department of Agricultural Economics and Rural Sociology at the Pennsylvania State University to accept the position of chief, Human Resources Branch, Economic Development Division, ERS, USDA.

Richard S. Cotter has been transferred from the dairy and poultry market news area office in Kansas City, Missouri, to serve as assistant chief of the Market News Branch of the Grain Division, C&MS, at Hyattsville, Maryland.

Peter J. Creyke, M.S. University of Maryland, is currently employed by Australia House, London, England.

John M. Curtis, head of the Department of Agricultural Economics at the University of Maryland, is on sabbatical leave from September 1, 1967, to February 1, 1968, at the East–West Center, Honolulu, Hawaii.

Lorand Dabasi-Schweng has accepted a two-year appointment as technical officer in the Land Use and Farm Management Branch of the Land and Water Development Division of the FAO.

Richard T. Dailey, Farm Production Economics Division, ERS, Pennsylvania State University, will join the faculty of the Department of Agricultural Economics, Washington State University. He will do exten-

sion and research work in farm management.

Marshall P. Danker, M.S. University of Illinois, is with the Peace Corps, in LaPaz, Bolivia.

James Dean received his master's degree in agricultural economics at the University of Kentucky and has accepted a position with the Department of State.

Martin L. Doordan, M.S. University of Maryland, is currently employed as an agricultural economist with the USDA.

John H. Droge, agricultural economist, Marketing Economics Division, ERS, USDA, has moved to a field office at the University of Wisconsin, where he will conduct research in fruit and vegetable processing.

William H. Ducommun, who completed his Master of Agriculture degree at Purdue University, has entered the armed services.

Kenneth Duft, who completed his Ph.D. at the University of California, Davis, joined the faculty of the Department of Agricultural Economics at Washington State University in September. He will do extension and research work in agricultural business management. He spent the previous year in London studying food distribution systems in Great Britain under a grant from the Rockefeller Foundation.

Edward V. Dunn has joined the staff of the Department of Agricultural Economics, North Dakota State University, as assistant professor. He will be responsible for the teaching and research program in livestock marketing. He has completed his M.S. degree at North Dakota State University.

Selmer A. Eugene, University of Minnesota, is in Argentina, where he is serving as project specialist in agricultural economics assigned to the Ford Foundation's field office in Buenos Aires during the fall and winter quarters. Dr. Eugene is continuing the services provided by Dr. Darrell F. Fienup, who has returned to the University of Minnesota for the 1967-68 academic year. Dr. Fienup will return to Argentina in the summer of 1968.

Richard F. Fallert, Marketing Economics Division, ERS, USDA, transferred from Washington, D.C., to Lafayette, Indiana. He is working toward a Ph.D. at Purdue University.

Kenneth R. Farrell has accepted appointment as director of the Marketing Economics Division, ERS, USDA. Dr. Farrell comes to the Department from the University of California at Berkeley, where he has been since 1957. Dr. Farrell replaces Kenneth E. Ogren, who has accepted the post of agricultural attaché in the U.S. Mission to OECD in Paris.

John R. Feagan has joined the staff of the Department of Agricultural Economics and Sociology, Texas A&M University, as extension economist in farm organization. He formerly was manager of the Hale Center Cooperative Gin Company, Hale Center, Texas.

C. Lynn Fife, Ph.D. Purdue University, has been appointed assistant professor of agricultural economics at the University of Vermont. He will work in the area of marketing and business management.

Lyndell W. Fitzgerald, who is completing his Ph.D. program at Purdue University, has accepted a position as associate professor of agricultural economics and extension

economist at the University of Minnesota.

Phillips W. Foster, Department of Agricultural Economics, University of Maryland, is on a Fulbright study leave during 1967-68 at Allahabad, India.

Mark L. Fowler, formerly of Oklahoma State University and at Texas A&M during 1963–1966, has joined the agricultural economics staff at Texas Technological College, with major responsibilities in the areas of price analysis, agricultural policy, and cotton marketing.

Robert Freeman has transferred from the Marketing Economics Division to the Economic Development Division, ERS, USDA. He was named group leader of the Housing Facilities Group in the Community Facilities Branch.

C. Kerry Gee, Farm Production Economics Division, ERS, USDA, Corvallis, Oregon, has been reassigned to Fort Collins, Colorado.

M. Riad El Ghonemy has been appointed chief, Land Tenure and Settlement Branch, Food and Agriculture Organization of the United Nations, Rome, Italy. Previously, he was land tenure specialist in the same Branch and FAO land reform adviser to some governments in Latin America.

Donald G. Gillette, employee of the Marketing Economics Division, ERS, USDA, has accepted a position with the National Center for Air Pollution Control, HEW, Durham, N.C. He received his Ph.D. from the University of Maryland in June 1967.

Clarence H. Girard retired from his position as deputy administrator for regulatory programs, Consumer and Marketing Service, USDA, on September 30, 1967. He had completed 39 years' government service, serving 26 of them with USDA in the Office of the General Counsel, Office of Hearing Examiners, as director of the Packers and Stockyards Division and as deputy administrator.

J. C. Grady, Jr., formerly economist with the Federal Reserve Bank in Dallas, has accepted the position of associate professor in the Department of Agricultural Economics and Sociology, Texas A&M University. He is engaged in teaching and research in marketing.

James W. Graves resigned from the staff at Texas A&M University to join the agricultural economics staff at Texas Technological College as associate professor on September 1, 1967.

Josef Grueter, who recently completed a M.S. degree at Iowa State, has joined the Department of Agricultural Business and Economics, University of Maine, as assistant professor. He has a research–teaching appointment in resource economics.

Thomas L. Guthrie has joined the Marketing Economics Division, ERS, USDA, and is stationed at Purdue University, where he is conducting economic research relating to the mixed feeds industry.

Gerald Hale received his master's degree in agricultural economics at the University of Kentucky and has accepted a position as area agent in agricultural economics with the Kentucky Cooperative Extension Service.

A. N. Halter is on sabbatical leave from Oregon State University for this academic year. He spent the summer months in Australia at the University of New South Wales. He will spend the current academic

year working in the Economics Department at Stanford University.

John K. Hanes, Marketing Economics Division, ERS, USDA, returned to Washington, D.C., in September 1967 after spending five years at the Horticultural and Special Crops Branch field station at the University of Minnesota.

Hosea S. Harkness, agricultural statistician formerly with the Agricultural Estimates Division of the Statistical Reporting Service, USDA, Washington, D.C., has been transferred to the Little Rock, Arkansas, State Statistical Office of the Service.

Clive R. Harston, Montana State University, has rejoined the staff of the Department of Agricultural Economics and Sociology as chief of party on the Texas A&M University–AID Project in Buenos Aires, Argentina.

Walter G. Heid, Jr., has been reassigned from the Marketing Economics Division to the Farm Production Economics Division of ERS, USDA, Bozeman, Montana.

Clarence J. Hein has resigned his position with the Economic Development Division, ERS, USDA, to accept a position as professor of public administration, University of Missouri, at Kansas City.

R. Burnell Held has resigned his position as chief of the Division of Research and Education to accept an appointment as professor of outdoor recreation in the College of Forestry and Natural Resources, Colorado State University.

Delmar Helgeson, formerly with the St. Paul Bank for Cooperatives in St. Paul, Minnesota, is now an instructor in the Department of Agricultural Economics at the University of Nebraska, working on an ERS–Nebraska farm input market study.

Glenn A. Helmers has resigned from the Farm Production Economics Division, ERS, USDA, Lincoln, Nebraska, to join the agricultural economics staff of the University of Nebraska.

Eithan Hochman, Ph.D. University of California, Berkeley, is now on the staff of the Department of Economics at the University of Tel Aviv in Israel.

John A. Hopkin, formerly a vice-president, Bank of America, San Francisco, became professor of agricultural finance, University of Illinois, in September 1967.

Douglas E. Horton, M.S. University of Illinois, is carrying on further graduate work in the Department of Economics at Cornell University.

Josiah Hoskins, a doctoral candidate in agricultural economics at the University of Kentucky, has accepted a position as resource development specialist at the University of Georgia.

James B. Hottel, Farm Production Economics Division, ERS, USDA, Fayetteville, Arkansas, has been reassigned to College Station, Texas, where he will continue with his program of research on the economics of rice production.

Donald J. Hunter has been appointed assistant professor in the Department of Economics at Iowa State University.

Thomas K. Hunter has joined the staff of the Department of Agricultural Economics and Sociology, Texas A&M University, as a grain marketing specialist in Extension.

Tom M. Irrer, who has completed his Master of Science degree at Purdue University, is farming in St. John, Michigan.

George T. Irwin, cooperative agent, Farm Production Economics Division, ERS, at Purdue University, is on nine-month assignment with the Agricultural Finance Branch of USDA in Washington. He will work on an evaluation of the Farm Credit Program.

Md. Shamsul Islam, professor and dean of the Faculty of Agricultural Economics and Sociology, East Pakistan Agricultural University, is a guest for six months in the Department of Agricultural Economics and Sociology, Texas A&M University, to observe teaching, research, and extension in agricultural economics.

Donald E. Jarrett, M.S. University of Illinois, is now associated with the Decatur Production Credit Association, Decatur, Illinois.

Earl A. Jenson has been appointed research associate in the Department of Economics at Iowa State University.

Satish C. Jha, Ph.D. University of Illinois, has returned to his position as deputy director of research, Indian Society of Agricultural Economics, Bombay, India.

James B. Johnson, who has been serving on a part-time basis with the Farm Production Economics Division of ERS, USDA, Corvallis, Oregon, is now a full-time staff member at that location.

Roger C. Johnson has accepted a position as associate professor in the Department of Agricultural Economics at North Dakota State University, effective December 1, 1967. His area of responsibility will be teaching and research in resource economics and farm management. He was formerly on the staff at the University of Wisconsin.

Amos D. Jones is attending the Woodrow Wilson School of Government and Foreign Affairs at the University of Virginia. He received a Career Education Award from the National Institute of Public Affairs for training during the year September 1967–June 1968.

E. Walton Jones, associate professor of economics at North Carolina State University, has been appointed field director of the Coastal Plains Regional Commission located in Raleigh, North Carolina.

L. L. Jones has joined the staff of the Department of Agricultural Economics and Sociology, Texas A&M University, with the rank of assistant professor. His work will be in the area of marketing.

Fred Justus, formerly professor of agricultural economics at the University of Missouri, has joined the staff as associate professor of agricultural economics at the University of Kentucky.

Norman Kallemeyn, Trade Statistics Analysis Branch, Foreign Development and Trade Division, ERS, has transferred to Foreign Agricultural Service, USDA, and has been assigned to Hong Kong as an assistant agricultural attaché.

Rex P. Kennedy has joined the agricultural economics staff at Texas Technological College as assistant professor in charge of farm and ranch management research and teaching.

Mark S. Kern, M.S. University of Illinois, accepted a position as instructor in agricultural business, Wabash

Valley Junior College, Mount Carmel, Illinois, in September 1967.

Govind J. Khudanpur, who received his doctorate in agricultural economics from the University of Kentucky, has returned to his duties at the Gokhale Institute of Politics and Economics, Poona, India.

Richard L. Kilmer, who recently completed his Master of Science degree at Purdue University, has entered the armed services.

F. Richard King, who completed the course requirements for the Ph.D. degree at the University of Connecticut, has joined the Department of Agricultural Business and Economics, University of Maine, as an extension specialist in agricultural business management.

E. Fred Koller, University of Minnesota, is on sabbatical leave for the winter quarter to study at the University of California, Berkeley.

Gerald Korzan has returned to the Department of Agricultural Economics at Oregon State University after a two-year foreign assignment in Syria.

Stanley F. Krause, Economic Development Branch, Foreign Development and Trade Division, ERS, USDA, has been named director of the Animal and Animal Products Division of the Farmer Cooperative Service.

George Kruer has been named assistant chief, International Monetary and Trade Research Branch, Foreign Development and Trade Division, ERS, USDA.

Allan M. Lackey, formerly with the Agricultural Stabilization and Conservation Service, has joined the Water Resources Branch, Natural Resource Economics Division, ERS, USDA.

Norman Landgren, leader of the Great Plains Resource Group, Natural Resource Economics Division, ERS, USDA, resigned October 1, 1967, to accept a position with Colorado State University. He will be chief of party and economist with an Agency for International Development group to West Pakistan on a two-year assignment.

Curtis F. Lard has joined the Department of Agricultural Economics and Sociology, Texas A&M University, as associate professor. His work is teaching and research in production economics. He formerly was associate professor of agricultural economics at the University of Tennessee.

Jose M. Lawas, who completed his Ph.D. at Purdue University, is with the Planning Board, Government of the Philippines, Laguna, Philippines.

Robert E. Lee, who completed his Ph.D. at Purdue University, is consultant to Arthur D. Little Co., Cambridge, Massachusetts.

Harold R. Linstrom has accepted a liaison economist position at the Southern Utilization Research and Development Division, ARS, USDA, New Orleans, Louisiana. This is one of four liaison economist positions that MED, ERS, maintains in a cooperative program with the USDA's regional laboratories. Mr. Linstrom spent the last four years at the University of Hawaii as a cooperative agent. He replaces O. C. Hester, who now heads the poultry situation work in the Economic and Statistical Analysis Division, ERS, USDA, Washington, D.C.

Gary L. Logan, who completed his

Master of Science degree at Purdue University, has entered the armed services.

J. Patrick Madden has finished his assignment with the National Advisory Commission on Rural Poverty and has accepted a position as associate professor of agricultural economics at the Pennsylvania State University.

Florian A. Maniecki of the faculty of agricultural economics, Warsaw Agricultural University, has resumed his duties after spending a year in postdoctoral study and research at the University of Kentucky.

J. Paxton Marshall, University of Maryland, was appointed associate professor of agricultural economics, Virginia Polytechnic Institute, September 1, 1967.

Leo V. Mayer has been appointed assistant professor in the Department of Economics at Iowa State University.

J. K. McDermott, Purdue University, has taken leave to accept an appointment as rural development officer, Agency for International Development Mission to Colombia, in Bogota.

John G. McNeely, Jr., who did his Ph.D. work at Oklahoma State University, has joined the staff of the Division of Agricultural Economics and Education at the University of Nevada as an assistant professor. He will work in the area of resource economics, with an appointment in teaching and research.

John W. Mellor of the Cornell University Department of Agricultural Economics is in New Delhi, India, this year pursuing his research on the role of prices in agricultural development.

Joseph F. Metz, Jr., will be directing the Cornell University Project at the College of Agriculture of the University of the Philippines, Los Banos, for most of the next two years.

Bruce A. Miller, who completed his Master of Science degree at Purdue University, is farming at Bicknell, Indiana.

Hermon I. Miller, director, Poultry Division, Consumer and Marketing Service, USDA, has announced plans to retire from government service on December 30, 1967. Mr. Miller will complete more than 33 years of government service, the last 20 of which were spent directing USDA programs of research, marketing, and regulatory services in the poultry field.

David G. Moorman, in process of completing Ph.D. requirements at Texas A&M University, joined the staff at Texas Technological College, September 1, 1967, as assistant professor.

Arthur T. Mosher has been elected president of the Agricultural Development Council. The Council supports programs related to the economic and human problems of agricultural development, primarily in Asia.

Bela Mukherjee-Mukhoti, formerly doing postdoctoral study and research at the University of Kentucky, has joined the Department of Economics at Memphis State University.

C. J. Murphrey, formerly extension farm management specialist, Department of Agricultural Economics and Sociology, Texas A&M University, has joined the Texas A&M University–AID Project as an agricultural economist in Santo Domingo, Dominican Republic.

Robert K. Naylor, a former graduate student in the Department of Agricultural Economics and Sociology, Texas A&M University, has joined the staff as a cooperative agent with the Marketing Economics Division of ERS.

John Paul Nelson, a doctoral candidate in the Department of Agricultural Economics at the University of Kentucky, has accepted a teaching position in the Department of Economics at the University of Louisville.

Khalil Omar, M.S. University of Maryland, is currently on diplomatic assignment in Egypt.

Merton L. Otto, professor of economics, Kansas State University, retired effective July 1, 1967, after more than 35 years of extension service and academic work at the University.

Earl J. Partenheimer has resigned from the Farm Production Economics Division, ERS, USDA, University Park, Pennsylvania, to join the agricultural economics staff of Pennsylvania State University.

Rodney Paul, Farm Production Economics Division, Economic Research Service, USDA, Fargo, North Dakota, has been reassigned to Ames, Iowa.

Frederick J. Poats has rejoined the staff of the Marketing Economics Division after a two-year assignment in Brazil. He will act as leader of the Utilization Economics Research Group, Market Development and Performance Branch, Marketing Economics Division, ERS, USDA.

Harry R. Potter shares a joint appointment between the Department of Sociology and the Department of Agricultural Economics, Purdue University, as leader of the Purdue phase of the AID–CIC contract to study the organization, administration, and impacts of AID–University contract projects in technical assistance.

Steve M. Raleigh, Jr., accepted a position as agricultural economist, Marketing Economics Division, ERS, USDA, in June 1967. He is in charge of research in horticultural specialties in the Horticultural and Special Crops Branch.

Philip M. Raup, University of Minnesota, has returned to the Department of Agricultural Economics after spending a year in Paris as a member of a research team which undertook work on a study of Europe and the North Atlantic Community.

Ian Reekie has completed requirements for his Ph.D. degree at North Carolina State University and has joined the Economics and Statistics Department of Unilever Limited, London, England. His work is concerned with analysis of the market for oils and fats.

Uri Regev recently completed his Ph.D. work at the University of California, Berkeley, and is now on the staff of the Department of Economics at the University of Tel Aviv in Israel.

Alan Reichardt, who recently completed an M.S. degree in agricultural economics at Oklahoma State University, has accepted an appointment in the Department of Agricultural Economics and Sociology, Texas A&M University, as extension farm management specialist at Weslaco.

David W. Riggs transferred from the Europe and Soviet Union Branch, FRAD, ERS, USDA, to the Foreign Agricultural Service in May 1967

and has accepted a position as assistant agricultural attaché in The Hague, Netherlands.

N. Keith Roberts has returned from two years on the USAID–Utah State University contract in Bolivia and has assumed the headship of the Department of Agricultural Economics and directorship of the Economics Research Institute at Utah State University.

Robert W. Rudd, professor of agricultural economics at the University of Kentucky, was appointed chairman of the department and began his work on August 1.

Jack L. Runyan, who recently received his M.S. degree from the University of Maryland, is currently pursuing a Ph.D. at the University of Maryland.

Carl R. Saathoff, who completed his Master of Science degree at Purdue University, is on the CIC Traveling Scholar Program at the University of Chicago. He will complete his Ph.D. at Purdue University.

L. L. Sammet, professor of agricultural economics, University of California, Berkeley, has been appointed vice-chancellor for research, Berkeley campus, effective October 1, 1967.

Richard F. Saunders, professor of agricultural business and economics, University of Maine, who has been on leave (1965–1967), has resigned his position. He is now a consultant with the Nathan Associates Economic Advisory Team to the Government of Afghanistan.

Phil W. Schleeter, M.S. University of Illinois, now has a supervisory position with the Moorman Manufacturing Company, Quincy, Illinois.

William R. Schroder, who completed his Ph.D. at Purdue University, is now research officer, Wool Research Organization of New Zealand, Christchurch, New Zealand.

Frank S. Scott, Jr., agricultural economist with the University of Hawaii, has joined the staff of the Department of Agricultural Economics and Sociology, Texas A&M University, and will be working in the Texas A&M University–AID Project in Argentina for two years.

Gerald L. Setter, who completed his Master of Science degree at Purdue University, is working for his Ph.D. at the University of Minnesota.

Jerry A. Sharples, Farm Production Economics Division, Economic Research Service, USDA, Ames, Iowa, has been reassigned to Washington, D.C., to work with the Production and Resource Response Group of the Production Adjustments Branch.

Rudie W. Slaughter, Jr., Ph.D. University of Illinois, is now a member of the staff of the Farm Production Economics Division, Economics Research Service, USDA.

Allen G. Smith has joined the staff of the Farm Production Economics Division of the Economic Research Service, USDA, Urbana, Illinois.

Harold D. Smith has been named acting head of the Department of Agricultural Economics at the University of Maryland, from September 1, 1967, to February 1, 1968.

Mostafa A. Soliman, who completed his Ph.D. degree at Iowa State University, has joined the faculty of the University of Minnesota as research associate in the Department of Agricultural Economics. Dr. Soliman's appointment is for one year and he is working with Dr. Willis Peterson in poultry marketing.

Leland Southard, formerly of Louisiana State University, has joined the staff of the Marketing Economics Division and has been assigned to the Market Statistics Research Group, Market Development and Performance Branch, Marketing Economics Division, ERS, USDA.

Martin S. Stauber, Jr., has resigned from the Farm Production Economics Division of the Economic Research Service, USDA, Columbia, Missouri, to join the agricultural economics staff of the University of Missouri.

J. T. Steele has accepted the position of agricultural economist for the Texas A&M University–AID Project in Buenos Aires, Argentina. He is completing a Ph.D. degree in agricultural economics at the University of Wisconsin.

Jerome Stein, who recently received his M.S. degree from the University of Maryland, is currently employed by the USDA.

Henry Stippler has returned to Corvallis, Oregon, after two years in Iraq. He is now retired from USDA–ERS.

Alexander Swantz is being appointed assistant deputy administrator for regulatory programs, C&MS, USDA, succeeding John C. Blum. Dr. Swantz has been staff economist, Office of the Administrator, Consumer and Marketing Service, since returning from a year's study at Princeton University in July 1966.

Max M. Tharp, chief of the Resource Services Branch of the Public Land Law Review Commission, resigned August 25, 1967, to accept a position as field program coordinator with the Natural Resource Economics Division, ERS, USDA.

James F. Thompson has been granted a year's leave of absence from the Department of Agricultural Economics, University of Kentucky, to serve as professor in the Department of Economics at Murray State University.

Erik Thorbecke, professor of economics at Iowa State University, will spend the next year in Washington, D.C., beginning September 1, 1967, where he will continue to serve as head of the Sector and Market Analysis Section of the Agency for International Development.

J. Robert Tompkin, who was granted a two-year leave of absence from the Farm Production Economics Division of the Economic Research Service, USDA, to work on the Ohio State University–AID project in Sao Paulo, Brazil, has returned to his headquarters in Columbus, Ohio.

Alan Y. Tsao has been appointed research associate in the Department of Economics at Iowa State University.

F. L. Underwood has accepted a second term in the position of agricultural economics advisor, Agricultural University, Mymensingh, East Pakistan. This work is a part of the Texas A&M University–AID project.

Laszlo Valko, Department of Agricultural Economics, Washington State University, spent from September to February in Austria, Germany, and Switzerland gathering data in connection with his research on the economic and social impact of cooperatives.

Payungsri Vichitrpahanakarn, who recently received his M.S. degree from the University of Maryland, is presently employed in the Division of Agricultural Economics, Ministry of Agriculture, Bangkok, Thailand.

Ronald J. Vogel, after receiving his Ph.D. degree from the University of Wisconsin last June, joined the faculty of Agricultural Economics at Cornell University on September 1, 1967, as assistant professor in public administration and finance, and is teaching an undergraduate course in taxation.

Kenny Wade received his master's degree in agricultural economics at the University of Kentucky and has accepted a teaching position at Morehead State University.

John J. Waelti has completed his Ph.D. degree at the University of California and has joined the faculty of the University of Minnesota as assistant professor and extension economist in the Department of Agricultural Economics and the Agricultural Extension Service. His responsibilities will be in the area of the economics of pollution control. He also will work with the University of Minnesota Water Resources Center.

Frederick Wayne Weber, formerly a graduate student at West Virginia University, has accepted an appointment with Economic Research Service, USDA, and is stationed at Morgantown, West Virginia.

Fred C. Webster has completed his year's leave to work with the Federal Extension Service in Washington, D.C., and is back with the Department of Agricultural Economics at the University of Vermont.

E. Boyd Wennergren has been assigned to the USAID–Utah State University contract in Bolivia for a period of two years. He will work on a project titled "Resource Development on the Bolivian Altiplano."

Clifton R. Wharton, Jr., has been elected vice-president of the Agricultural Development Council. The Council supports programs related to the economic and human problems of agricultural development, primarily in Asia.

Lawrence A. Witucki, formerly of the University of Wisconsin, has joined the Economic Development Branch, Foreign Development and Trade Division, ERS, USDA. He will do research on technology and economic development.

Donnie Wright received his master's degree in agricultural economics at the University of Kentucky and has accepted a position teaching economics in the University's Community College System at Hopkinsville.

Victor W. Zanotti completed the requirements for an M.S. degree in agricultural economics at West Virginia University during the summer and has accepted a position with the Soil Conservation Service as a watershed economist, with headquarters at Morgantown, West Virginia.

Hassan Sid Abu Zeid, M.S. University of Maryland, is employed by the Ministry of Agriculture and Forests, Khartoum, Sudan.

Glenn A. Zepp, Farm Production Economics Division, Economic Research Service, USDA, University Park, Pennsylvania, has been reassigned to Storrs, Connecticut.

OBITUARIES

Paul T. Blair, 44, died July 13, 1967. He earned the B.S. and M.S. degrees at Mississippi State University and the Ph.D. degree at the University of Florida He was a professor in the Department of Agricultural Economics at Mississippi State University for thirteen years. He received national and international recognition for his work in research and education in agricultural cooperation. Dr. Blair's outstanding accomplishments in his chosen field earned for him positions of responsibility with the Mississippi Council of Farmer Cooperatives and the American Institute of Cooperatives. The ability he exhibited as chairman and cochairman of the Research and Education committees of these organizations, and in developing director training programs for cooperatives, caused cooperative organizations not only in the state, but also throughout the nation, to look to him for leadership.

Robert H. Blosser, professor of agricultural economics at Ohio State University, died in Columbus, Ohio, September 29, 1967. Professor Blosser was born near Bremen, Ohio, July 30, 1909. He graduated from Rushcreek High School in Bremen, Ohio, and received his Bachelor of Science degree in agriculture at Ohio State University in 1931. He did graduate work in agricultural economics at Ohio State, where he earned the Master of Science degree in 1937. He served as a farm planner with the U. S. Soil Conservation Service in Fayette County, Ohio, from 1946 to 1949. In 1949, he joined the faculty of the Ohio Agricultural Experiment Station as an associate professor. Since that date, he has been a member of the faculty of the Department of Agricultural Economics and Rural Sociology at the Ohio Agricultural Research and Development Center and the Ohio State University. Professor Blosser was the author of many research and scientific articles and research bulletins in the area of farm management. He was considered an authority in the area of cost of production research.

Raymond Bressler, Jr., died in Berkeley, California, on January 8, 1968, at the age of 56 after a long illness. He had been a prominent member of the American Farm Economic Association for many years. He served as president of the Western Farm Economics Association in 1954-55 and as president of the American Farm Economic Association in 1959-60. He was elected Fellow of the Association in 1963. He brought to the field of agricultural economics a broad training in agricultural and mechanical engineering and applied this experience in pioneering work in economic-engineering studies of processing plant costs and efficiency. This phase of his work yielded developments of both theoretical and empirical significance. Much of his early research involved studies of pricing efficiency in milk marketing, a major product of which was a Ph.D. dissertation, "City Milk Distribution," for which he was awarded the Wells prize at Harvard University and which subsequently was published in book form. Emphasis on the spatial aspects of the pricing structure led to a strong interest in the theoretical and applied aspects of plant location and interregional competition. His most recent work, as yet largely un-

published, centered on new approaches to the measurement of production-function relationships.

With his thorough grounding in economic theory and quantitative methods, a wide knowledge of the institutions and structure of the agricultural economy, a keen and analytical mind, the gift of articulate expression, enthusiasm and humor, he was a valued contributor to countless industry, public, and professional meetings; and his services were widely sought as a consultant to both federal and state agencies and private agencies. His greatest contribution was in his teaching, which not only strongly reflected and supported his research but also was marked by its clarity, consideration for the student, and capacity to excite an enlightened and lasting interest.

For nearly 20 years, from July 1, 1948, he was a member of the faculty in Agricultural Economics of the University of California, Berkeley, where he also served as department chairman and director of the Giannini Foundation of Agricultural Economics from 1952 to 1957. He served the Berkeley campus as vice chancelor from 1962 to 1964, as director of curriculum revision in 1965-66, and as director of the Office of Institutional Research in 1966-67. Prior to appointment in the University of California, he was a member of the agricultural economics faculty of the University of Connecticut, 1939–48, and executive secretary of the New England Research Council, 1937–39; and he held posts in two federal agencies, the Agricultural Adjustment Administration and the Works Progress Administration, 1936-37. He was awarded the B.S. degree in agricultural engineering at Pennsylvania State University in 1932, and in mechanical engineering at Rhode Island State University in 1933; the M.S. degree in agricultural economics at the University of Connecticut in 1936; and the Ph.D. degree in economics at Harvard University in 1947.

Those who wish to contribute to a Raymond G. Bressler, Jr., Student Loan Fund may send checks, payable to The Regents, University of California, to The Gifts and Endowments Office, Room 100, Building T-7, University of California, Berkeley, 94720. The name of the fund and the donor should be clearly indicated in a cover letter. The Bressler family have indicated their approval of this memorial in lieu of other testimonials. Mrs. Bressler is living at No. 1, Rock Lane, Berkeley, California 94708.

Nellis A. Briscoe, professor of agricultural economics at Oklahoma State University, his wife, and their six children were killed in a traffic accident on August 3, 1967, near Highland, Illinois. They were en route to the annual meeting of the American Institute of Cooperation at Purdue University. Dr. Briscoe was born at Lincoln, Kansas, on September 7, 1918. He received his bachelor's and master's degrees from Fort Hayes Kansas State College in 1948 and 1952, respectively, and his Ph.D. degree from Oklahoma State University in 1955. He served with the United States Navy during World War II. Dr. Briscoe joined the staff of the Department of Agricultural Economics at Oklahoma State University as assistant professor in 1945 and was advanced to full professorship in 1965. Working in the field of marketing, he was best known professionally for the depth of his understanding of cooperative business organization and management and for the leadership which he gave in that field. At the time of his death, he was secretary of the Long Range Planning Com-

mittee for the American Institute of Cooperation and a member of the Youth Education Consulting Committee. He had been appointed to the Land-Grant College Committee of the Institute for the coming year. He was recognized by students and co-workers as a dedicated teacher and researcher and by people in a broad area of agriculture for his keen perception of marketing problems. A review of his writings shows that they covered a wide range of interests. His influence in the agribusiness field was felt nationally and, in recognition, the American Institute of Cooperation has voted to name its college scholarship the "Nellis A. Briscoe Scholarship." Another Briscoe Memorial Scholarship is being developed at Oklahoma State University.

Aubrey J. Brown, professor of agricultural economics at the University of Kentucky, died in Lexington, Kentucky, on January 8, 1968, after an illness of several months. Dr. Brown was born in Hemple, Missouri, on July 3, 1913. He attended the University of Illinois, where he received a B.S. degree in civil engineering in 1935, an M.S. in 1937, and the Ph.D. in 1946, with a major in agricultural economics. He joined the faculty of the University of Kentucky in 1938. He became head of the Department of Markets and Rural Finance in 1946, and in 1952 became chairman of the newly created Department of Agricultural Economics, a post he held until the time of his illness in mid-1967.

At the University of Kentucky, Dr. Brown's service included a three-year tour as one of the first faculty members of the University's Board of Trustees, and service for 16 years as a member of the Board of Directors of the U.K. Athletic Association.

Dr. Brown served on the Editorial Council of the *Journal of Farm Economics* (1950–54) and as vice-president of the American Farm Economic Association (1959). He served six years as a member of the Board of Directors of the Federal Reserve Bank of Cleveland. He was a member of the National Tobacco Industry Advisory Committee and the Agricultural Committee of the American Bankers Association.

Dr. Brown's research includes published works in livestock marketing and tobacco marketing. His research in the latter area was conducted in Spain and the United Arab Republic as well as in the United States.

In his memory, the Aubrey J. Brown Memorial Fund for Aid to Students from Rural Areas has been established at the University of Kentucky.

Kendall S. Carpenter, professor of business administration in the Cornell University Department of Agricultural Economics, died from a heart attack on June 13, 1967, at the age of 50 years, after 13 years on the Cornell staff. At the time of his death, Dr. Carpenter was secretary of the New York State Council of Farmer Cooperatives, vice-president of the University Credit Union, and a director of Cayuga Lodge Co-op, a student cooperative residence. He was a recipient of the Professor of Merit award by students in the College of Agriculture. He was also recipient of the Empire State Farmer degree. Professor Carpenter was a native of Groton, Vermont, a graduate in 1938 from the University of Vermont, and the recipient of the M.S. and Ph.D. degrees at Cornell University in 1951 and 1953, respectively.

Leo M. Hoover, professor of agricul-

tural economics at Kansas State University, died June 6, 1967, at the age of 56. He earned a bachelor's degree at Kansas State University, a master's degree at Iowa State University, and a doctorate at Harvard University. Professor Hoover was a farm management specialist with the Farmers Home Administration immediately prior to and following service in the U.S. Army during World War II. He also served as consultant to the Bureau of Employment Security, U. S. Department of Labor. His primary responsibilities at Kansas State University were teaching and research in farm management. From July 1966 to January 1967, Professor Hoover was in Nigeria as head of the Department of Agricultural Economics at Ahmadu Bello University, Zaria. He is survived by his widow and six children.

Thomas E. Tramel, 46, died July 26, 1967. He earned the B.S. and M.S. degrees at Mississippi State University and the Ph.D. degree at Iowa State University. Dr. Tramel was a professor in the Department of Agricultural Economics at Mississippi State University for 19 years. He was currently serving as director of institutional research, consultant to the Computing Center, and member of the Graduate Council. He was an authority in farm management, production economics, statistics, and research methodology. His papers represented major contributions to the solution of problems that plagued economists for years. He was unsurpassed as a teacher and his talents were widely sought as advisor to agencies of the government and other universities. Dr. Tramel was recognized as one of the leading agricultural economists in the nation. He received national and international recognition for his work in mathematical economics, statistics, and programming. He participated in the development of reactive programming, which represented a major breakthrough in solution procedures used in spatial equilibrium analysis.

AMERICAN FARM ECONOMIC ASSOCIATION

SUSTAINING MEMBERS—1967

AGWAY INCORPORATED
Syracuse, New York

ANDERSON, CLAYTON COMPANY
Houston, Texas

ATCHISON, TOPEKA & SANTA FE RAILWAY SYSTEM
Amarillo, Texas

BROWN & WILLIAMSON TOBACCO CORPORATION
Louisville, Kentucky

CALIFORNIA PACKING CORPORATION
San Francisco, California

CARGILL, INCORPORATED
Minneapolis, Minnesota

CONTINENTAL GRAIN COMPANY
New York, New York

COTTON PRODUCERS ASSOCIATION
Atlanta, Georgia

DEERE & COMPANY
Des Moines, Iowa

DEERE & COMPANY
Moline, Illinois

F. S. SERVICES
Bloomington, Illinois

FARMLAND INDUSTRIES INCORPORATED
Kansas City, Missouri

GREEN GIANT COMPANY
Minneapolis, Minnesota

H. P. HOOD & SONS
Boston, Massachusetts

GEORGE A. HORMELL & COMPANY
Austin, Minnesota

INDIANA FARM BUREAU COOPERATIVE ASSOCIATION
Indianapolis, Indiana

INTERNATIONAL HARVESTER COMPANY
Chicago, Illinois

KROGER COMPANY
Cincinnati, Ohio

NORTHWEST MUTUAL LIFE INSURANCE COMPANY
Millwaukee, Minnesota

OSCAR-MEYER COMPANY
Madison, Wisconsin

PEAVY COMPANY
Minneapolis, Minnesota

PIONEER HI-BRED CORN COMPANY
Des Moines, Iowa

RALSTON PURINA COMPANY
St. Louis, Missouri

REGISTER & TRIBUNE
Des Moines, Iowa

STAPLE COTTON COOPERATIVE ASSOCIATION
Greenwood, Mississippi

SUCCESSFUL FARMING
Des Moines, Iowa

TRAVELER'S INSURANCE COMPANY
Hartford, Connecticut

WEITZ-HETTELSATER ENGINEERS
Des Moines, Iowa

WILSON & COMPANY
Chicago, Illinois

Selected business firms are invited to become Sustaining Members of the American Agricultural Economics Association. These include firms that have a natural interest in the long-run economic strength of the nation's agriculture. While the association wishes to have the support of these members in all of its activities, they are being particularly looked to for support in the several awards programs being sponsored by the association.

JOURNAL OF BUSINESS

Graduate School of Business, University of Chicago, Chicago, Illinois 60637

Volume 40 OCTOBER 1967 Number 4

Product Life Cycles as Marketing Models .... *William E. Cox, Jr.*
The Spread of a Cost-Free Business Innovation .... *Julian L. Simon and Leslie Golembo*
Computer Algorithms for Finding Exact Rates of Return .... *Seymour Kaplan*
The Variation of Some Other Speculative Prices .... *Benoit Mandelbrot*
Advertising and Liquor .... *James M. Ferguson*
Discrimination and Apprentice Regulation in the Building Trades ..... *Richard L. Rowan*
The Refunding Decision .... *Eli Schwartz*
Earning Probabilities and Capital Costs .... *Glen A. Mumey*
Special Section on Organizational Innovation ....
.... *edited by Selwyn W. Becker and Thomas L. Whisler*
The Innovative Organization: A Selective View of Current Theory and Research ....
.... *Selwyn W. Becker and Thomas L. Whisler*
Innovation-Resisting and Innovation-Producing Organizations ...... *Herbert A. Shepard*
A Descriptive Model of the Intra-Firm Innovation Process .... *Kenneth E. Knight*
Organizational Structure and Innovation .... *Harvey M. Sapolsky*
Some Determinants of Organizational Success .... *Selwyn W. Becker and Frank Stafford*
Innovation in Business Organizations: Some Factors Associated with Success or Failure of Staff Proposals .... *William M. Evan and Guy Black*
A Note on Departmental Autonomy and Innovation in Medical Schools ...... *Jean Carroll*

Book Reviews

Books Received

Notes: University Schools of Business

The JOURNAL OF BUSINESS is published quarterly by the University of Chicago Press. Subscriptions are $8.00 per year and should be addressed to the University of Chicago Press, 5750 South Ellis Avenue, Chicago, Illinois 60637. Manuscripts in duplicate, typed and double-spaced (including footnotes and quotations), and editorial correspondence should be addressed to Irving Schweiger, Editor, JOURNAL OF BUSINESS, Graduate School of Business, Haskell Hall, University of Chicago, Chicago, Illinois 60637.

JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION

Volume 62 **December 1967** **Number 320**

The Quantification of Judgment—Some Methodological Suggestions ..... *Robert L. Winkler*
Designing Some Multi-Factor Analytical Studies .... *J. Sedransk*
Representation of Similarity Matrices by Trees .... *J. A. Hartigan*
On Some Invariant Criteria for Grouping Data .... *H. P. Friedman and J. Rubin*
Some Observations on Robust Estimation .... *Robert V. Hogg*
Rank Analysis of Covariance .... *Dana Quade*
On Some Multisample Permutation Tests Based on a Class of μ Statistics .... *P. K. Sen*
On Some Optimal Nonparametric Procedures in Two-Way Layouts .. *M. L. Puri and P. K. Sen*
Optimal Robustness: A General Method, with Applications to Linear Estimators of Location .... *Eugene Laska and Allan Birnbaum*
Efficiency Robust Two-Sample Rank Tests .... *Eugene Laska and Allan Birnbaum*
Asymptotic Distribution for a Generalized Banach Match Box Problem .... *T. Cacoullas*
The Maximum Likelihood Estimate of the Non-Centrality Parameter of a Non-Central Variate .... *Paul L. Meyer*
Approximate Specifications and the Choice of a K-Class Estimator ...... *Franklin M. Fisher*
An Application of Variable Weight Distributed Lags .... *P. A. Tinsley*
The Variance of Weighted Regression Estimators .... *James S. Williams*
A Necessary and Sufficient Condition that Ordinary Least Squares Estimators Be Best Linear Unbiased .... *F. W. McElroy*
Asymptotic Variances for Dummy Variate Regression under Normality Assumptions ..
.... *Stanley L. Warner*
Computer Simulation Experiments with Economic Systems: The Problem of Experimental Design .... *Thomas H. Naylor, Donald S. Burdick and W. Earl Sasser*
A Computer Simulation Model of the Textile Industry ....
.... *Thomas H. Naylor, William H. Wallace and W. Earl Sasser*
Straight Line Confidence Regions for Linear Models ...... *Leroy Folks and Charles E. Antle*
Statistical Dependence between Random Effects and the Number of Observations on the Effects for the Unbalanced One-Way Random Classification .... *David A. Harville*
Correlated Errors in the Random Model .... *Bruce M. Hill*
Sequential Analysis of Variance under Random and Mixed Models .... *B. K. Ghosh*
Migration of Employed Persons .... *Ann R. Miller*
Method of Constructing of Attrition Life Tables for Single Population ..... *Joginder Kumar*
Book Reviews

For further information, please contact

AMERICAN STATISTICAL ASSOCIATION, 810 18th Street, N.W., Washington, D.C. 20006